PEDIATRIC SURGERY AND MEDICINE FOR HOSTILE ENVIRONMENTS

Kevin M. Creamer, MD • Michael M. Fuenfer, MD



Second Edition

Pediatric Surgery and Medicine for Hostile Environments

Second Edition

Borden Institute
US Army Medical Department Center and School
Health Readiness Center of Excellence
Fort Sam Houston, Texas

Office of The Surgeon General
United States Army
Falls Church, Virginia

The test of the morality of a society
is what it does for its children.

—Dietrich Bonhoeffer (1906–1945)

This book is dedicated to the military medical professional in a land far from home, standing at the bedside of a critically ill child.

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Foreword

The top priority for the Joint Health Services Enterprise is readiness and health. In support of Combatant Commanders, a key component of readiness is the ability to deploy responsive medical capabilities: these include the provision of medical care to the full spectrum of patients that may present to our deployed medical facilities.

Traditionally, military planning for medical support of combat operations has not included provisions for pediatric care. However, in response to unexpectedly large numbers of children presenting to US military medical facilities for treatment in the Iraq and Afghanistan theaters, the Borden Institute published a book, based on the pediatric experiences of deployed providers, that would serve as a basic reference for providers of pediatric care in practice environments with limited resources. The 2010 edition of *Pediatric Surgery and Medicine for Hostile Environments* significantly enhanced the ability of deployed military physicians whose scope of practice is primarily limited to adults in diagnosing and treating many of the most common medical and surgical conditions of childhood. This book has served as an invaluable resource for US military physicians caring for children in some of the most austere and hazardous environments imaginable, whether at a US Army battalion aid station, medical company, Forward Surgical Team, or Combat Support Hospital operating at a Forward Operating Base; in flight aboard US Air Force aircraft during medical evacuation operations; aboard Navy hospital or other surface ships; or in fixed medical facilities around the world.

In this second edition, the content of each chapter has been thoroughly reviewed to reflect the most current and relevant clinical information. Additional chapters have been added based upon feedback from medical providers at all echelons of care, representing each of the uniformed services. The contributors—military pediatric surgeons and physicians—have pooled their collective wisdom and experience gained through countless months and years of clinical practice and deployments into the content of this book, which is unique in its objectives.

Beyond its demonstrated utility to the US military, hundreds of copies of *Pediatric Surgery and Medicine for Hostile Environments* have been requested by and distributed to foreign military and civilian practitioners as well as nongovernmental organizations. To further enhance its utility, the Borden Institute has made the full content of the book available at no cost online (http://www.cs.amedd.army.mil/borden).

This book supports the highest ideals of US military medicine: to provide exceptional medical care, at all times, under any condition, to all people. I extend my thanks to the selfless contributors, editors, illustrators, and reviewers whose time and effort has produced this second edition of an outstanding publication.

Lieutenant General Nadja Y. West, MD
The Surgeon General, US Army
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Prologue

Since this book's initial publication in 2010, comprehensive reviews of the pediatric care provided in Afghanistan and Iraq by military medical treatment facilities (MTFs) have helped define the scope of the pediatric wartime mission.[1,2] From 2001 to 2011, a total of 7,505 patients under the age of 18 and 6,270 patients under the age of 15 were admitted to deployed Role 3 facilities.[1] While these patients comprised 5.8% of total admissions, they comprised 11% of all bed days. Interestingly, the majority of admissions for patients under the age of 15 were for noncombat-related conditions, either blunt injury from falls or motor vehicle collisions, burns in the home, elective surgeries, or medical conditions. This was especially the case in Afghanistan, a country with little existing medical infrastructure at the beginning of the war; however, in both Iraq and Afghanistan, pediatric combat-related admissions and noncombat-related admissions increased during the troop surges, reflecting the increased need for care of medical and surgical diseases in children when the conflicts escalated. During times of war, children are not only "caught in the crossfire," but suffer due to the chaotic environment and resulting destabilization of local infrastructure and services.[1–4]

Many lessons have been learned from the past decade regarding pediatric inpatient care in austere environments. Military MTFs and personnel must be prepared for the longer-term care of critically ill and injured children. This includes the transition from the MTF to the local medical facility and ultimately the patient's community. Unlike our injured soldiers, who are typically evacuated out of theater via critical care air transport teams in 12 to 24 hours, children generally must remain in the austere environments where they were injured. We have learned that embarking on treatment regimens that cannot be supported long term in these environments are ultimately not beneficial.

Overall pediatric mortality rates from trauma were higher than adult civilians and significantly higher than US coalition forces.[1] We have identified the factors most associated with pediatric trauma mortality, including Injury Severity Score, Glasgow

Coma Scale (GCS) score, base excess, younger age (less than 8 years), burn injury, and, interestingly, female gender.[1] Females were also more likely to be younger and admitted with a burn or another medical issue, perhaps related to a variety of societal dynamics.[5] Another study found a strong association of base deficit and coagulopathy with mortality in these patients.[6] A separate analysis utilized this data to derive a trauma "BIG Score," which includes base deficit, international normalized ratio (INR), and GCS score, to predict mortality. This score was validated with civilian data (primarily blunt trauma).[7] All these studies underscore the fact that head injuries and poor physiologic status at presentation are obstacles to successful treatment. They also suggest that local culture and social norms will inevitably affect the children who present for care.

The conflicts of the past decade were notable for the overwhelming impact of the improvised explosive device. This weapon was responsible for the majority of pediatric combat injuries in Afghanistan and second only to gunshot wounds in Iraq. The blast injury complex, which became the face of the combatant casualties of this war, wrought similar havoc on civilians, both adults and children. In comparison to adults, blast-injured children were more likely to sustain a head injury and tended to have a higher Injury Severity Score and longer hospital stays, and require more operative interventions. One unique finding was that children who were burned as a result of a blast had a much higher mortality than those who were not.

While a significant number of children were cared for at well-equipped and relatively well-staffed combat support hospitals, many children also sought care at Role 1 and 2 facilities under much more austere conditions, and little data is available documenting these encounters. Although much light has now been shed on the scope of the mission of pediatric combat casualty care, what is not clearly known are the outcomes. While pediatric in-hospital mortality was significantly higher than that seen in US hospitals, and significantly higher in patients under the age of 8 (compared to 9- to 18-year-olds), it is difficult to make comparisons between the two given disparities in equipment, facilities, provider background and experience, overall

conditions, and the baseline health of the patients. Long-term outcome measures beyond survival to discharge are not available. As a result, the ability to critically analyze the outcomes of these children is very limited and makes performance improvement challenging.[1,8]

Clearly there is a need for a robust pediatric registry to accurately capture data for outcomes analysis and mission preparation. The Department of Defense Trauma Registry has emerged as a powerful tool for improving combat casualty care in adults, and fueled the development of clinical practice guidelines. Implementation of these guidelines has resulted in improved outcomes for adults. Applying established adult clinical practice guidelines to children sometimes seems intuitive, but should be done with caution given lack of a proven benefit. Some examples of this are the use of tranexamic acid and also balanced component blood product resuscitation in pediatric patients. Unfortunately, using this type of registry for pediatric data analysis is fraught with problems involving capture of important data points (eg, weight, appropriate GCS score, recording blood products in specific volumes). It is essential to improve pediatric data capture as far forward as possible. Enhanced data acquisition systems will also facilitate more appropriate placement of pediatric subspecialty providers and more appropriate and useful predeployment training to those who do not have significant pediatric experience.

We hope that this text provides military physicians, often practicing in austere environments, with a current and concise reference for the basic medical, surgical, and critical care of children. It should be used as a pragmatic reference but not as a substitute for current peer-reviewed articles or reasoned judgment. Operative procedures performed on children require careful assessment of the available resources and equipment, experience of the operating room team, potential complications, nonoperative options, availability of follow-up care, and an honest overall assessment of the risk to the child from the procedure to be undertaken. Fortunately, the operative procedures done to care for these patients are largely within the scope of practice of well-trained general and orthopedic surgeons.[3]

Despite wartime conditions, it is still our ethical obligation to counsel a patient's parent or guardian, if available, about the risks and benefits of a procedure, and to obtain their consent for nonemergent operations. Local customs and the family's desires must be respected in all cases, lest what was intended to be a humanitarian gesture results in unintended consequences that negatively impact the success of the overall military mission.

While much remains to be learned regarding optimizing pediatric combat casualty care, one fact is clear: the preparation for future conflicts and operations must include consideration of the sick and injured child, especially for those not primarily trained in pediatric critical care and surgery. This revised text is designed to support the men and women in uniform who continue to provide the best care possible for the smallest patients under the worst possible conditions.

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Introduction

Military Humanitarianism: Caring for Children in Disaster *Our Past and Future*

In 2012, two-thirds of the world's population was living in a country affected by a natural disaster or major conflict.[1] In the summer of 2014, Iraq, Syria, the Central African Republic, and South Sudan all experienced United Nations "level three" emergencies based on the number of people affected, the situation's urgency and complexity, and the capacity of the local government to respond.[2,3] The number of displaced people in these countries exceeded 8 million, adding to the over 50 million displaced across the globe, numbers higher than any time since World War II.[2] Many of those affected were children. The US military has frequently been called to respond to these types of crises, consistent with our long history of involvement in humanitarian emergencies.

As early as 1803, President Thomas Jefferson sent Captains Merriweather Lewis and William Clark on what remains the longest infantry patrol in US history. The explorers traveled 8,000 miles in 28 months. Military humanitarianism was one of the key goals of their mission as they surveyed the health habits of Native American tribes and provided direct medical care to them and to local civilian settlers.[4–6] Lewis and Clark were also prepared to provide smallpox vaccination to the "Indians," at the behest of President Thomas Jefferson.

The Indian Campaigns of the late nineteenth century were the first instance of America's Armed Forces being permanently posted on its frontiers. Military medical officers shared all the hardships of post life and practiced military humanitarianism regularly. In the 1880s, Colonel William H Arthur was stationed at Fort Washakie on the Shoshone and Arapahoe Indian Reservations. He wrote:

> I was there two years without ever seeing another doctor of any kind, and had to give medical care to the small garrison, to all the Indians on the reservation, about 4,000 . . . and to all

the cowboys, miners and odds and ends of civilians found on the frontier, who came in for a radius of 150 miles.[7]

After the Spanish American War, humanitarianism motivated Major Walter Reed's research to discover the vector for yellow fever. After he had definitively proven the virus's association with the *Aedes aegypti* mosquito, he wrote, "The prayer that has been mine for 20 or more years—that I may be permitted in some way, for some time, to do something to alleviate human suffering—has been answered."[8]

In World Wars I and II, the American Red Cross and other nongovernmental agencies were closely embedded with and assisted by the military when providing humanitarian aid to civilians. The military bore the additional burden for the logistics of humanitarian support in World War II due to the scope of the devastation and disruption to civilian communities.[9]

In the immediate aftermath of the destruction of Hiroshima in 1945, Dr Hachiya Michihiko commented on the impact of US military doctors who assisted him in treating Japanese civilians, saying, "They gave us great help, materially and spiritually in the reconstruction of our hospital. Two doctors removed fear and hostility from our hearts and left us with a bright, new hope." Dr Michihiko finished his book with this thought: "When I think of the kindness of these people, I think one can overlook thoughts of revenge; and even at this moment, I feel something warm in my heart when I recall those days and those friends."[10]

In 1946, Colonel Ogden Bruton established a 90-day pediatric training course for military physicians after a number of infants died accompanying their soldier fathers and European mothers on returning troop ships. Many point to this course as the genesis of pediatric training in the military.[11]

The beginning of the Cold War was punctuated by perhaps the most famous example of military humanitarianism: the 1947 Berlin Airlift, in which an entire city was supported with millions of pounds of supplies by air for fifteen months.[12]

The "Armed Forces Aid to Korea" program provided emergency medical aid to Korean civilians, as well as education programs for Korean doctors and nurses during the Korean conflict. Supplies, funds, and technology for the construction of hospitals were also included in the program. US soldiers donated cash to the program staffed by volunteer Army doctors and nurses. Eventually, more than $3.5 million was collected and 320,000 medical procedures were performed.[13]

In Vietnam, the 3rd Marine Division operated a 110-bed children's hospital near the Vietnamese Demilitarized Zone. It was staffed by Navy pediatricians, surgeons, and medical officers and saw more than 250 outpatient visits a day and 100 admissions a month. Lieutenant "Skip" Burkle, working alongside Vietnamese medical personnel, reported an epidemic of bubonic plague in children, the scourge of war and refugees. Dr Burkle, a pediatrician, was in the Marine Children's Hospital when it came under fire and was severely damaged in the September 1968 Tet Offensive.[14]

Throughout the decades following the Vietnam conflict, the Department of Defense (DoD) participated in several large international relief missions, including operations Sea Angel in Bangladesh (1991), Restore Hope in Somalia (1992–1993), Support Hope in Rwanda (1994), Restore Democracy in Haiti (1994), and the response to Hurricane Mitch (1998) in Central America.[15,16] In the conflict in Kosovo, the care of civilian children was regular practice among pediatricians deployed with the Army (MAJ Mark Burnett, MC, USA, personal communication, April 4, 2001).

Operation "Provide Comfort" in Northern Iraq in 1991 is recognized for ushering in a decade of military humanitarianism and established the US military as collaborative experts in humanitarian disaster relief.[15,16] Subsequent efforts during Operations Desert Storm and Desert Shield inspired a group of Army pediatricians to establish the "Military Medical Humanitarian Assistance Course" under the auspices of the Department of Pediatrics at the Uniformed Services University in Maryland. This training, coupled with extensive experience in

humanitarian civic assistance projects, resulted in hundreds of DoD medical professionals becoming experts in refugee medicine and humanitarianism.[17]

Since 2001, the care of civilians and the development of civilian healthcare systems in Iraq and Afghanistan have been foundational to nation-building efforts. The care of children by uniformed providers in military healthcare facilities has been at the center of these efforts.[17–23] DoD continues to be actively engaged around the world, responding to the challenges of natural and human-made disasters, including the 2014 Ebola epidemic in sub-Saharan Africa.[24,25]

Humanitarian disasters today—compounded by climate change, economic threats (eg, financial, food, and fuel), the changing nature of conflict, and sexual violence—disproportionately affect women and children.[27] At the same time, medical professionals recently completing training may actually have less experience in caring for ill children. Recently I stood over an old surgical textbook in a primitive operating room with two surgeons, struggling to figure out how to save a 2-day-old infant with imperforate anus in sub-Saharan Africa. Clearly there remains a great need for resources like this book. Unfortunately, there will be abundant opportunity for its use.

Our national strategy focuses on opportunities to avoid conflict by promoting peace.

Major General John Pearn, former Surgeon General of the Australian Defense Force, summarized his experience as follows: "Pediatrics and preventive medicine, as it applies to children, are no longer discretionary skills for all who serve in the health disciplines within the broader profession of arms."[26] As we focus our national energy on the care of infants and young families in desperate situations around the world, what impression will we leave? What will the young child be told as she grows up about the men and women who cared for her as a newborn? As we respond with expertise to the care of children in other nations, will our good efforts ultimately be an investment in the kind of national security we would hope to leave for our children?

This book is for those engaged in this fight for the world's children. We dedicate it to everyone standing at the bedside of a critically ill child in a dangerous place far from home.

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Resuscitation and Critical Care

Chapter 1

Basic Approach to Pediatric Trauma

Background

- Recent epidemiologic reviews of pediatric wartime injuries have found significantly higher trauma mortality rates for infants, younger children, and females.
- Extremity injuries are the most frequent injuries overall.
- Children injured by explosive devices demonstrate a unique blast pattern primarily involving injury to the face and neck with associated burns, and result in a higher mortality.
- Independent predictors of mortality on presentation include Glasgow Coma Scale (GCS) score less than 4, shock (base deficit ≥ 6), and coagulopathy (international normalized ratio ≥ 1.5).
- Triage for pediatric trauma is similar to that for adults. It is a system used to prioritize treatment, taking into account the extent (ie, polytrauma or a single injury) and type of trauma (ie, blunt or penetrating) or illness.

Anatomic and Physiologic Considerations

- Vital signs are based on age (Table 1-1).
- Abnormal general appearance is indicative of a serious illness or injury.
- Normal responses differ by age (ie, developmental stages).
- Both bradypnea and bradycardia are ominous.
- Children have a greater body surface area-to-weight ratio than adults, increasing risk of hypothermia.
- Hypothermia increases oxygen demand and predisposes to apnea and bradycardia.
  - Obtain rectal temperature; monitor and maintain temperature at 36.5°C to 37.5°C.
  - The head is a major source of heat loss; mitigate heat loss by covering the head with a hat or cap.

Table 1-1. Normal Vital Signs by Age Group

Age	Weight (kg)*	Respiratory Rate (Breaths/Min)	Heart Rate (Beats/Min)	Systolic Blood Pressure (mmHg)†
Premature infant	< 3	40–60	130–170	45–60
Term newborn (< 28 days)	3	35–60	120–160	60–70
Infant (1 mo–1 y)	4–10	25–50	110–150	70–100
Toddler (1–2 y)	10–13	20–30	90–130	75–110
Young child (3–5 y)	13–18	20–30	80–120	80–110
Older child (6–12 y)	18–40	15–25	70–110	90–120
Adolescent (13–18 y)	> 40	12–20	55–100	100–120

*Weight norms based on US children. Expect lower weights in countries where malnutrition is more prevalent.
†For children 1 to 10 years old, use the following equation: 70 + 2 (age) = lowest acceptable systolic pressure for age.

- Children have greater insensible water loss and have different fluid requirements than adults (see Chapter 25, Basic Fluids and Electrolytes).
- The larynx is funnel shaped, cephalad, and anterior. The cricoid is the narrowest portion of the airway. An infant's trachea is approximately 5 cm long and a toddler's is approximately 7 cm long.

- The pediatric skull has expandable sutures until 18 to 24 months of age.
- Children's short, fat necks make assessing for tracheal deviation or jugular venous distention difficult.
- Cervical spine fractures are less common than ligamentous injury, and higher-level cervical injury is more common. Spinal cord injury without radiographic abnormality can be seen in up to 50% of children with spinal cord injuries.
- Highly elastic ribs make fractures less likely; transmitted energy is more likely to cause pulmonary contusion.
- Tension pneumothorax is more likely in children than in adults due to the mobile contents of the mediastinum.
- Solid abdominal organs are more susceptible to injury because of their proportionally larger size, closer proximity to each other, limited protection by ribs, and less-developed abdominal walls with limited muscle and subcutaneous fat.
- Fractures of long bones with active growth plates can result in length discrepancies.
- Special considerations for neonates (≤ 28 days) and young infants:
  - This age group is at increased risk for sepsis due to decreased white blood cell function and count, decreased antibody synthesis, and decreased inflammatory response.
  - Neonates are more sensitive to drugs because of their immature blood–brain barrier.
  - Hypoglycemia is more common in this age group because of neonates' smaller glycogen stores.
  - Neonates' smaller functional residual capacity makes desaturation more common.
  - Apnea and bradycardia may occur in response to decreased partial pressure of oxygen and increased carbon dioxide.
  - Hypocalcemia will result in hypotension; intravenous (IV) calcium is an inotrope in young infants.
- Psychological impact considerations:
  - Very young children may regress in response to pain, stress, or perceived threats.
  - Involving a parent or guardian may help in calming the child and acquiring a history.

  - See Chapter 37, Behavioral Healthcare of Pediatric Patients in an Austere Environment.
- Medications are all dosed as units per kilogram per dose. Use a Broselow tape for emergency equipment sizing and medication dosing (see inside back cover) as well as a reference for all routine pediatric drug doses (eg, *The Harriet Lane Handbook*). See Appendix C for a comprehensive pediatric equipment table.

The Pediatric Assessment

- With the 2010 American Heart Association Basic Life Support update, increased emphasis is placed on the rapid identification of pulselessness and early initiation of cardiopulmonary resuscitation.
- For unresponsive patients, begin with the sequence of C-A-B instead of A-B-C: chest compressions (or circulation), airway, and breathing/ventilation. If pulselessness is identified, begin basic life support with high-quality cardiopulmonary resuscitation and proceed with advanced management according to Pediatric Advanced Life Support (PALS) algorithms (inside front cover).
- For responsive patients, begin with a PALS rapid cardiopulmonary assessment using the pediatric assessment triangle in the first seconds based on visual and auditory cues to determine if the condition is life-threatening.
  - Appearance: assess for alertness, color, speech, motor function, eye contact, and whether the child is distractible.
  - Work of breathing: assess for abnormal sounds (wheezing, stridor, grunting), positioning, retractions, and nasal flaring.
  - Circulation to skin: assess for temperature, pulse, and capillary refill time.
- The pediatric assessment triangle allows for rapid categorization of pediatric illness.
  - Increased work of breathing indicates respiratory distress.
  - Increased work of breathing with abnormal appearance indicates respiratory failure.
  - Abnormal color indicates further observation is needed.

  - Abnormal color with abnormal appearance indicates shock.
  - Abnormal appearance only indicates brain dysfunction.
- Following the initial rapid PALS assessment, begin the Advanced Trauma Life Support primary survey, which is a hands-on assessment based on the ABCDE (airway, breathing, circulation, disability, exposure) approach and should take no more than 5 to 10 minutes.
- Life-threatening conditions should be treated as soon as they are identified.

Airway

- The most common cause of cardiac arrest in children is respiratory failure.
- Determine if the child's airway is clear, maintainable with simple maneuvers, or compromised, needing advanced interventions.
- A child's relatively large tongue and prominent occiput cause the head to flex forward and potentially obstruct the pediatric airway. The child's head should be placed in the sniffing position (Figure 1-1). Use a jaw thrust if injury to the cervical spine is a concern.
- Position and suction the airway as necessary; consider placing an oropharyngeal (in an unconscious patient) or nasopharyngeal airway.
- Indications for endotracheal (ET) intubation include any of the following:
  - GCS score less than or equal to 8.

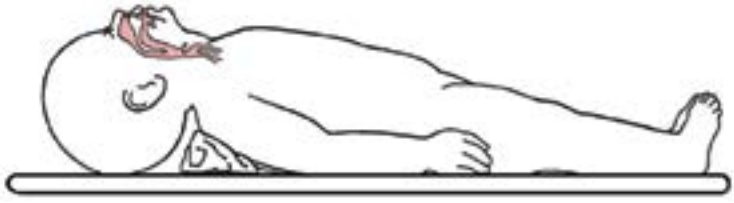


Figure 1-1. Pediatric airway positioning.

- No protecting airway reflexes (cough, gag).
- Inability to oxygenate, despite intervention.
- Inability to ventilate, despite intervention.
- Prolonged transport.
- Hemodynamic benefit (hypotension, cardiac arrest).

- Performing rapid sequence intubation:
  - Preoxygenate with 100% oxygen by a nonrebreather mask for 2 minutes or 4 vital capacity breaths.
  - Administer an appropriate adjunct, induction agent (or agents), and neuromuscular blockade (Table 1-2).
  - Apply cricoid pressure using the thumb and index finger.
  - Perform direct laryngoscopy using appropriately sized equipment (see Appendix C).
    - ET tube size is rapidly estimated as: (age in years + 16)/4.
    - Consider rounding down in malnourished patients.
  - Place ET tube under direct visualization.
    - Cuffed ET tubes are recommended for children older than 8 years.
    - If there is expected need for high-ventilation pressures (ie, pulmonary contusions or edema), early placement of cuffed ET tubes, sized 0.5 mm smaller than expected for age, may be appropriate.
  - Confirm tube position with examination (ie, bilateral auscultation, adequate chest rise) and quantitative capnography or qualitative carbon dioxide detection.
  - Release cricoid pressure.
  - Secure tube.
  - Confirm with chest radiograph, if available.
- For patients unable to be intubated, transtracheal ventilation via needle cricothyroidotomy is a rescue airway option.
  - Use a 14- to 16-g IV catheter connected to a resuscitation bag with a 2.5 or 3.0 ET tube adapter.
  - Alternatively, use a 14- to 16-g IV catheter connected to a 3-mL syringe with the plunger removed; connect the syringe to a resuscitation bag with a 6.5 or 7.0 ET tube adapter.
- Tracheostomy is preferred; surgical cricothyroidotomy should not be performed in children under 12 years of age due to risk of long-term trauma.

Table 1-2. Rapid Sequence Intubation Drugs and Doses

Drug	Dose	Characteristics
Adjunct		
Atropine	0.01–0.02 mg/kg IV/IM; min 0.1 mg, max 1 mg	Vagolytic; use if < 1 y or < 5 y and receiving succinylcholine
Lidocaine	1–2 mg/kg IV	May decrease ICP during RSI
Sedative/Anesthetic		
Etomidate	0.2–0.3 mg/kg IV	Few cardiovascular effects; decreases cerebral metabolic rate and ICP
Fentanyl	2–4 μg/kg IV/IM	May cause respiratory depression, hypotension, chest-wall rigidity
Ketamine	1–2 mg/kg IV 3–5 mg/kg IM	May increase heart rate, blood pressure and secretions; recommended for hemodynamic instability
Midazolam	0.1–0.3 mg/kg IV	May cause hypotension, respiratory depression; no analgesia
Propofol	2 mg/kg IV	May cause hypotension, particularly in hypovolemic patients
Thiopental	2–5 mg/kg IV	Negative inotrope; decreases cerebral metabolic rate and ICP
Paralytic		
Rocuronium	0.6–1.2 mg/kg IV	Few cardiovascular effects
Succinylcholine	2 mg/kg IV (infant) 1 mg/kg IV (child) Double dose for IM	Recommend coadministration of atropine if < 8 y; contraindicated with history of malignant hyperthermia, skeletal muscle myopathies, acute phase injury following major burns/polytrauma

ICP: intracranial pressure
IM: intramuscular
IV: intravascular
RSI: rapid sequence intubation

Breathing

- Assess for age-appropriate respiratory rate. Tachypnea greater than 60 breaths per minute is abnormal for any age.
- A declining respiratory rate to an expected age norm may be reassuring if it is associated with improved appearance; however, with worsening appearance, such a decline may be indicative of impending respiratory failure.
- Assess efficacy of respiratory effort on examination. Signs of respiratory distress include:
  - retractions (inspiratory);
  - grunting (expiratory), which indicates airway or alveolar collapse;
  - inspiratory stridor, which indicates extrathoracic obstruction; and
  - wheezing, which indicates intrathoracic obstruction.
- Assess efficacy of ventilation based on chest wall excursion and air movement on auscultation.
  - Decreased air entry is a sign of parenchymal lung disease or poor effort.
  - Hypoventilation is common in pediatric trauma.
  - Avoid hypercarbia.
- Apply supplemental high-flow oxygen and positive-pressure, bag-valve mask ventilation as necessary.
  - Deliver 1 breath every 3 to 5 seconds (12 to 20 breaths/min) for nonintubated patients, and every 6 to 8 seconds (8 to 10 breaths/min) with an advanced airway in place.
  - Deliver enough volume to generate good chest rise.
- Perform needle decompression, then insert a chest tube for tension pneumothorax (diagnostic signs and symptoms include hypoxemia, hypotension, and absent breath sounds).

Circulation

- Observe the child's mental status; level of reactivity and responsiveness are usually a reflection of cerebral perfusion.
- Compare central and peripheral pulse rate and quality.
- Observe capillary refill time. Normal is less than 2 seconds; longer than 3 seconds can indicate shock.

- Evaluate the patient's skin temperature centrally and distally using the back of the hand. Cooler extremities may indicate poor distal perfusion. Patient temperature should also be considered in the context of the room temperature.
- Rapidly identify ongoing hemorrhage and control bleeding.
- Begin cardiorespiratory monitoring with 3-lead electrocardiography and pulse oximetry; determine heart rate and rhythm.
- Measure blood pressure and pulse pressure early.
  - A child can still be in shock with a normal blood pressure (compensated shock).
  - Low blood pressure for the child's age indicates decompensated shock.
- Establish vascular access (intraosseous if necessary).
  - Treat shock and hypotension aggressively (see Chapter 6, Hemodynamics and Shock).
  - The preferred isotonic fluid is either 0.9% normal saline or Lactated Ringer's.
  - The standard bolus volume for a child is 20 mL/kg, repeated twice up to 60 mL/kg total.
- Blood products should be transfused if a resuscitation volume greater than 60 mL/kg is necessary, though earlier transfusion should be considered for hemorrhagic shock. Use a bolus of 10- to 15-mL/kg packed red blood cells for blood replacement (see Chapter 5, Transfusion Medicine).
- Diagnose and treat pericardial tamponade. Diagnostic signs and symptoms include tachycardia, pulsus paradoxus, and narrow pulse pressure, as well as Beck's triad (systemic hypotension, muffled heart sounds, and jugular venous distension). Tamponade may precipitate cardiac arrest with pulseless electrical activity.

Disability

- Quantify modified GCS score (Table 1-3).
- Evaluate for signs of neurological deficit and/or increased intracranial pressure, such as headache, vomiting, altered mental status, pupillary dilation, or posturing.
- Cushing's triad (irregular respirations, hypertension, and bradycardia) is a late finding of neurological decline.

Table 1-3. Modified Glasgow Coma Scale

Activity	Infant	Child/Adult	Score
Eye Opening	Spontaneous	Spontaneous	4
	To speech	To speech	3
	To pain only	To pain only	2
	No response	No response	1
Verbal	Coos and babbles	Oriented, appropriate	5
	Irritable cries	Confused	4
	Cries to pain	Inappropriate words	3
	Moans to pain	Incomprehensible sounds	2
	No response	No response	1
Motor	Moves spontaneously and purposefully	Obeys commands	6
	Withdraws to touch	Localizes painful stimulus	5
	Withdraws to pain	Withdraws to pain	4
	Abnormal flexion posture to pain	Flexion in response to pain	3
	Abnormal extension posture to pain	Extension in response to pain	2
	No response	No response	1

Data source: *The Merck Manual*. Traumatic Brain Injury. Modified Glasgow Coma Scale for Infants and Children. Table 3. http://www.merckmanuals.com/professional/injuries_poisoning/traumatic_brain_injury_tbi/traumatic_brain_injury.html?qt=&sc=&alt=. Accessed October 31, 2014.

- Spinal cord injury may present with neurogenic shock, a type of distributive shock characterized by loss of sympathetic tone with peripheral vasodilation, hypotension with wide pulse pressure, and sometimes bradycardia.
- Minimize secondary brain injury by avoiding or aggressively treating hypotension, hypoxemia, hyperthermia, hypercarbia, and hyperglycemia.
- Consider administering 2 to 4 mL/kg of 3% hypertonic saline to decrease intracranial pressure and help restore intravascular volume.

Exposure

- Look for other injuries and be wary of heat loss.
- Adjuncts to the primary survey include cardiorespiratory monitoring, pulse oximetry, end-tidal carbon dioxide, arterial blood gas monitoring, urinalysis, placement of a Foley or gastric catheter, and radiographs (chest, pelvis, lateral cervical spine).

Secondary Survey

- The secondary survey should be completed in 10 to 15 minutes and includes a focused history and detailed head-to-toe examination, with particular attention to identifying all injuries requiring surgical intervention.
- The SAMPLE pneumonic (signs/symptoms, allergies, medications, past medical history, last meal, and events) is often used to obtain the focused history.
- Standard secondary survey adjuncts include complete blood count; coagulation studies; liver function, amylase, and lipase tests; blood type and cross match; computed tomography scans; complete cervical spine series (including thoracolumbar spine if necessary); and angiography (if necessary and available).
- Prioritize management of injuries found in secondary survey.
- Inadequate resuscitation is common; continuously reassess vital signs and airway, breathing, and circulation.

Further Reading

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Chapter 2

Anesthesia

Pediatric trauma anesthesia varies significantly from adult trauma anesthesia because of the anatomical and physiological differences between adults and children (Table 2–1).

Table 2-1. Anatomical Considerations

Airway Anatomy	Implications
Infants have a large occiput, anterior airway	The traditional sniffing position will flex the infant's large head downward and is not helpful; place a rolled towel under the shoulders to facilitate intubation
Small airway means small endotracheal tube	Tube can easily become plugged with blood or secretions
Cricoid is the narrowest part of the airway	Ensure leak at less than 20–25 cm H_2O pressure to avoid edema*
Short trachea	Endobronchial intubation is common; making auscultation of bilateral breath sounds imperative; extubation can be caused by small movements of the head or ET tube
Infants have increased airway reactivity	Bronchospasm is common, especially during light anesthesia or if ET tube is near the carina
Infants have an increased dead space/minute ventilation ratio	Increased risk of rebreathing carbon dioxide; avoid adding connectors between ET tube and Y-piece of the circuit

ET: endotracheal
*For significant pulmonary contusions and edema, short-term cuff pressure > 25 cm H_2O may be needed and outweighs long-term risks. Ventilating pediatric patients is difficult with manually adjusted field anesthesia machines. Intensive-care-unit-grade ventilators are more effective at generating exact tidal volumes and can be used with intravenous anesthesia.

Physiological Considerations

- Infants and small children are unable to increase their stroke volume, making them dependent on heart rate to maintain cardiac output.
- In infants less than 6 months old, consider using atropine before induction or rapid sequence intubation to maintain heart rate (see Chapter 1, Basic Approach to Pediatric Trauma, Table 1-1 for normal vital signs).
- **Hypoventilation** is the most common cause of cardiac arrest in children.
- **Respiratory acidosis**, further exacerbating a metabolic acidosis, is a common occurrence in injured children.
- **Hypotension** is a late sign of **hypovolemia** in children.
  - Blood pressure usually remains normal until more than 25% blood volume is lost.
  - Poor perfusion, evidenced by cool extremities, delayed capillary refill, and diminished distal pulses, is an early sign of hypovolemia.
  - The most common causes of hypotension in pediatric patients are hypovolemia or excessive concentrations of volatile anesthetics once under anesthesia.
- If the patient is not responding to volume, medications may be needed to increase blood pressure.
  - Phenylephrine **should not** be a first-line choice for treating intraoperative hypotension in children.
  - Small doses of epinephrine are a better first-line choice.
    - Start with 1 to 4 μg and titrate to effect.
    - At low doses, the β effects of epinephrine predominate, increasing heart rate and contractility.
  - Consider a continuous infusion of inotropes or pressors if hypotension persists despite adequate fluid and blood product resuscitation. Dopamine and epinephrine are the preferred vasopressor infusions for pediatric patients.

Intubation

- Indications include altered level of consciousness, impending or actual upper airway obstruction, and hemodynamic instability.

- Orotracheal intubation is the most reliable means of establishing an airway and ventilating a child. The risk of penetrating the cranial vault or injuring the nasopharyngeal soft tissue is a relative contraindication to the use of the nasotracheal route in patients less than 12 years old.
- In head-injured or comatose patients, intubation should be performed with cervical spinal immobilization.
- Video laryngoscopes can be a useful adjunct when intubating patients with cervical spine immobilization.
- For chronically malnourished children, consider starting with a slightly smaller tube.

Airway Formulas

- Ways to estimate the appropriate endotracheal tube size:
  - (Age + 16)/4
  - Height (cm)/20
  - Size of child's small finger (fifth digit on hand)
  - Premature infant: 2.5
  - Term infant: 3.0
- Ways to estimate appropriate depth of endotracheal tube (cm; from tip to lip):
  - Infant: 6 + weight (kg)
  - Child: 3 × size (inner diameter) of tube
- **NOTE:** These are only estimates; always evaluate clinically.

Surgical Airway

In infants and small children, cricothyroidotomy may cause long-term damage to the larynx, so tracheostomy is preferred. Cricothyroidotomy can be safely performed in children older than 11 years.

Initial Ventilator Settings

- Set tidal volume to 7 to 10 mL/kg.
- If using pressure control, peak inspiratory pressure (PIP) should be 20 to 25 cm H_2O.
- Positive end-expiratory pressure (PEEP) should be 3 to 5 cm H_2O.
- Age-appropriate respiratory rates:

  - Adolescents: 10 to 15 breaths per minute (bpm)
  - Children: 15 to 25 bpm
  - Infants: 25 to 30 bpm
- Titrate minute ventilation to achieve end tidal carbon dioxide 35 to 40 mmHg.
- Fraction of inspired oxygen should be set to 100% initially, then titrate to nontoxic levels as permissible.

Pediatric Equipment Sizing

In an emergency, the preferred method of determining equipment size for pediatric patients is using the Broselow Pediatric Measuring Tape (see inside back cover). To use the tape, measure the patient from the top of the head to the heels and use the equipment and drug doses indicated on the tape. For central line sizes, refer to Chapter 3, Vascular Access. Otherwise, refer to the equipment table in Appendix C.

Pediatric Trauma Resuscitation

Acidosis, hypothermia, and coagulopathy are a deadly triad for patients presenting with major exsanguinating trauma.

Hypothermia

- Pediatric patients are predisposed to hypothermia because of their large surface-area-to-weight ratio, thin skin, and paucity of subcutaneous fat.
- Hypothermia worsens preexisting acidosis by causing a leftward shift in the oxyhemoglobin dissociation curve, leading to decreased oxygen delivery to the tissues.
- It can cause decreased drug metabolism and, in infants, can lead to apnea and hypoglycemia.
- Aggressive rewarming and normothermia maintenance must be initiated immediately upon a pediatric trauma patient's arrival. Strategies for increasing or maintaining body temperature include, but are not limited to:
  - increasing the room temperature,
  - using forced-air warmers,
  - preparing and working on one body part at a time while leaving the rest of the child covered, and

  - wrapping the child's body and head in plastic bags.
- Fluid-warming devices are helpful; however, the volume of fluid and blood products administered to the pediatric patient must be controlled. One way to do this is to use a syringe at the end of the warming line to carefully measure the volume of intravenous (IV) fluids and blood products being given.

Fluid Resuscitation

- In cases where blood products are not the initial therapy of choice, begin fluid resuscitation with a 20 mL/kg bolus of normal saline (NS) or Lactated Ringer's (LR).
  - The best locations for large-bore IV access are the saphenous veins; for difficult patients consider the hands, feet, scalp, underside of wrist, or external jugular vein.
  - If IV access is not rapidly achieved (in 1–3 min), immediately proceed to intraosseous (IO) access.
  - Resuscitate through the IO access and then obtain reliable IV access.
  - IO sites along the proximal tibia and distal femur can be used.
  - The patient should be reassessed after each bolus of NS to evaluate whether more fluid or a change to blood is required.
  - If the child remains hypotensive after three 20 mL/kg boluses, administer 10 to 20 mL/kg packed red blood cells.
- For small IV catheters (22 gauge and 24 gauge), bolusing with a 10- to 20-mL syringe is the most efficient way to rapidly deliver fluids and blood products (see Table 2-2 for maintenance fluid recommendations).

Table 2-2. Maintenance Fluid Requirements

Weight (kg)	Intravenous Fluid Rate
Up to 10	4 mL/kg/h
10–20 kg	40 mL/h + 2 mL/kg/h for each kg > 10
> 20 kg	60 mL/h + 1 mL/kg/h > 20 kg

- Small children (< 2 years old) can occasionally become hypoglycemic during long operative cases. The tendency toward hypoglycemia is usually counterbalanced by the stress response of surgery. If potential hypoglycemia is concerning, run a maintenance-only infusion using an infusion of D_5 0.45% NS (do not include glucose in any of the resuscitation fluids to avoid hyperglycemia).

Monitoring

- All patients should have American Society of Anesthesiologists standard monitors in place (blood pressure cuff, electrocardiogram, pulse oximetry, temperature, capnometry).
- Consider placing an arterial line if large fluid shifts or frequent blood draws are anticipated.
  - Arterial lines can be placed in the radial, posterior tibial, or dorsal pedis arteries (< 5 kg use 24 g, > 5 kg use 22 g).
  - A femoral arterial line can be placed if other sites are unavailable, but requires a longer catheter.

Blood Therapy

- See Chapter 5, Transfusion Medicine, for guidance on routine and massive transfusion strategies.
- Hypocalcemia is associated with rapid infusion of colloids, including blood products (particularly fresh frozen plasma and fresh warm whole blood).
  - Severe cardiac depression and hypotension can result from ionized hypocalcemia (potent inhalational agents dramatically exacerbate hypotension).
  - Do not routinely transfuse at a rate faster than 1 mL/kg/min.
  - Prevention includes limiting the rate of fresh frozen plasma transfusion to less than 1 mL/kg/min and administering calcium chloride (5 mg/kg) or calcium gluconate (15 mg/kg) via a central line if available. When both are available, calcium gluconate is preferred, as calcium chloride can sclerose peripheral veins.
- To minimize coagulopathy if a patient is at risk for massive transfusion (> ½ circulating blood volume), packed red blood cells and fresh frozen plasma should be transfused in a 1:1

ratio, with appropriate alternating weight-based repletion of platelets and cryoprecipitate, if available (see Chapter 5, Transfusion Medicine, for details).

Burns (see also Chapter 12, Burns)

- In children with unrecognized inhalational injuries, severe airway swelling may occur after fluid resuscitation.
- If there is uncertainty about whether an inhalational injury has occurred, intubate early.
- In addition to maintenance fluids (see Table 2-2), use the Parkland formula to estimate additional resuscitation fluids in the first 24 hours based on body weight (BWt) and total body surface area (TBSA) burned:
  - Adult: 4 mL × BWt (kg) × TBSA (%)
  - Pediatric: 3 mL × BWt (kg) × TBSA (%)
- Use LR as the resuscitation fluid in the first 24 hours.
- Give half of resuscitation fluids in the first 8 hours, half over the next 16 hours.
- For patients that weigh less than 30 kg, use D_5LR for maintenance fluids.
- The goal is to give enough fluids to maintain a urine output of 1 mL/kg/h for children weighing less than 30 kg, and 0.5 to 1 mL/kg/h in adults.
- Consider pulmonary injury, carbon monoxide poisoning, and chemical exposure, particularly in closed-space burns.
- Consider airway burns and edema when patient presents with discolored sputum.
- Nutritional support is critical; start tube feedings as soon as possible postoperatively.
- Blood loss during burn excision: 3% of blood volume for every 1% of BSA excised.
- Blood loss during skin grafting: 2% of blood volume for every 1% of BSA grafted.

Preoperative Sedation

Children who require repeated operations after sustaining initial trauma will benefit from preoperative sedation. However, the effects of most preoperative anxiolytics will extend into the postoperative period. In children for whom IV access has been

established, dose-adjusted preoperative sedation regimens similar to those used in adults are appropriate.

- For children without IV access, the following are some of the available options:
  - Oral: **midazolam** 0.5 to 1 mg/kg (maximum dose 20 mg) 20 minutes prior to the procedure.
  - Rectal: **methohexital** 25 to 30 mg/kg, for children weighing less than 15 kg. Mix 500 mg methohexital with water to a volume of 5 mL (100 mg/mL).
  - Intramuscular:
    - 0.2 mg/kg **midazolam**, and
    - 2 to 5 mg/kg **ketamine**, and
    - 5 to 10 μg/kg **glycopyrrolate**.
    - Use midazolam 5 mg/mL to minimize volume.

Postoperative Pain Management

- Use a continuous IV opioid infusion (Table 2-3) if unable to use patient-controlled analgesia (PCA).

Table 2-3. Intravenous Narcotics: Continuous Infusion*

Drug	Loading Dose	Continuous Infusion
Morphine	0.05 mg/kg	0.01–0.06 mg/kg/h
Fentanyl	1 μg/kg	0.2–3 μg/kg/h
Hydromorphone	10 μg/kg	0.5–4 μg/kg/h

*Bolus to achieve analgesia and start infusion at a lower rate. If analgesia is inadequate, rebolus with half the first dose, and increase rate by 25%.

- Respiratory depression or arrest is a known complication of continuous narcotic infusions, and continuous pulse oximetry monitoring is indicated.
- Infants less than 6 months old can have decreased metabolism and narcotics clearance, which requires consideration when administering frequent narcotic doses or a continuous infusion. Children with a significant narcotic use history can, however, develop tolerance quickly and require escalating doses.
- PCA is usually suitable for children older than 6 years (Table 2-4).

Table 2-4. Patient-Controlled Analgesia Dosing*

Drug	Dose	Basal Rate	Lock out
Morphine	10–30 μg/kg	5–30 μg/kg/h	6–12 min
Fentanyl	0.25–1.0 μg/kg	0.25–1 μg/kg/h	6–12 min
Hydromorphone	2–6 μg/kg	1–3 μg/kg/h	6–12 min

*Patient-controlled analgesia can be used in a normal, cooperative child as young as 6 years old.

  - Communication must be sufficient to ensure both the patient and parent understand appropriate PCA use.
  - Loading dose is the same as for continuous infusion.
  - Basal rates are associated with overdoses in adults; monitor closely or avoid if possible.
  - Prevent the family from pushing PCA button.
- Intermittent IV opioid dosing is as follows:
  - **Morphine**: 0.05 to 0.1 mg/kg IV every 5 to 10 minutes, titrate to effect. Use this total dose as basis for IV every 2- to 4-h dosing.
  - **Fentanyl**: 0.5 to 1 μg/kg IV every 5 to 10 minutes, titrate to effect. Use this total dose as basis for IV every 1- to 2-h dosing.
- Oral opioids and other adjuvant medications
  - **Acetaminophen** has opioid-sparing effects.
    - IV: 2 years: 7.5 to 15 mg/kg/dose every 6 h, max 60 mg/kg/day. 2 to 12 years: 15 mg/kg/dose every 6 h, max 75 mg/kg/day.
    - Oral: 10 to 15 mg/kg every 4 to 6 h; max 75 mg/kg/day.
    - Per rectum: 25 to 45 mg/kg load, then 10 to 20 mg/kg every 6 h, max 100 mg/kg/day.
  - **Ketorolac**
    - Dose: 0.5 mg/kg IV every 6 h for no more than 5 days.
    - Avoid if patient is less than 6 months old or has renal dysfunction.
  - **Tramadol** is a weak μ opioid receptor agonist. Dose: 1–2 mg/kg orally every 6 h, max 400 mg/day.
  - **Acetaminophen with codeine**
    - Codeine dosing is 0.5 to 1 mg/kg/dose orally every 4 to 6 h, max 60 mg/dose.

    - Dose is limited by maximum daily dose of acetaminophen.
    - 25% of patients cannot convert codeine to its active formulation, and it will not be effective in these patients.
    - Adjust codeine dose in the presence of renal or liver dysfunction.
  - **Oxycodone**
    - Oral: 0.05 to 0.15 mg/kg/dose every 4 to 6 h, max 10 mg/dose.
    - If combined with acetaminophen, daily dose is limited by maximum dose of acetaminophen.
- Consider proactively adding a laxative while patient is on narcotics.

Regional Anesthesia

Regional anesthesia (Tables 2-5–2-7) may be contraindicated by shock or sepsis at initial presentation, but can be effective after initial stabilization and is usually performed while the child is anesthetized.

- Cardiorespiratory monitoring should be used for all patients less than 6 months old receiving continuous infusions, and for all patients receiving clonidine.

Table 2-5. Pediatric Caudal or Epidural Blocks Dosing

Age	Bupivacaine	Ropivacaine	Clonidine	Fentanyl
Single Injection				
< 1 y	0.25%, 1 mL/kg	0.2%, 1.2 mL/kg	1 μg/kg	2 μg/mL
> 1 y	0.25%, 1 mL/kg, max 20 mL	0.2–0.5%, max 20 mL or 3.5 mg/kg	1 μg/kg	2 μg/mL
Continuous Infusion				
< 6 mo	0.0625%, 0.2 mg/kg/h	0.1%–0.2%, 0.2 mg/kg/h	0.15 μg/kg/h	2 μg/mL
6–12 mo	0.125%, 0.3 mg/kg/h	0.1-0.2%, 0.3 mg/kg/h	0.15 μg/kg/h	2 μg/mL
> 1 y	0.125%, 0.3–0.4 mg/kg/h	0.1%–0.2%, 0.4 mg/kg/h	0.15 μg/kg/h	2 μg/mL

Reproduced from: Buckenmaier C, Bleckner L. *Military Advanced Regional Anesthesia and Analgesia Handbook.* Washington, DC: Borden Institute; 2009: Table 30-2.

Table 2-6. Pediatric Spinal Dosing

Age	Bupivacaine (mg/kg)	Tetracaine* (mg/kg)	Ropivacaine (mg/kg)
Infants	0.5–1	0.5–1	0.5–1
1–7 y[†]	0.3–0.5	0.3–0.5	0.5
> 7 y[†]	0.2–0.3	0.3	0.3–0.4

*With tetracaine, use epinephrine wash (epinephrine aspirated from vial and then fully expelled from the syringe prior to drawing up local anesthetic) to increase duration up to 120 minutes.
[†]Additives: clonidine 1–2 μg/kg for children > 1 year of age.
Reproduced from: Buckenmaier C, Bleckner L. *Military Advanced Regional Anesthesia and Analgesia Handbook.* Washington, DC: Borden Institute; 2009: Table 30-3.

Table 2-7. Drug Dosing for Pediatric Single-Injection Peripheral Nerve Block*

Block	Dose Range (mL/kg)	Midrange Dose (mL/kg)	Maximum Volume (mL)
Parascalene	0.2–1	0.5	20
Infraclavicular	0.2–1	0.5	20
Axillary	0.2–0.5	0.3	20
Paravertebral	0.5–1	0.7	5
Femoral	0.2–0.6	0.4	17
Proximal sciatic	0.3–1	0.5	20
Popliteal	0.2–0.4	0.3	15
Lumbar plexus	0.3–1	0.5	20

*Children < 8 y: 0.2% ropivacaine or 0.25% bupivacaine. Children > 8 y: 0.5% ropivacaine or 0.5% bupivacaine. **Do not exceed maximum recommended doses of local anesthetic.**
Reproduced from: Buckenmaier C, Bleckner L. *Military Advanced Regional Anesthesia and Analgesia Handbook.* Washington, DC: Borden Institute; 2009: Table 30-4.

- Lower the infusion rates of continuous bupivacaine and ropivacaine, due to immature liver metabolism in infants less than 6 months old that may lead to drug accumulation.
- Spinal anesthesia is more commonly performed in awake patients and is used as the primary anesthetic for surgery.

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Chapter 3

Vascular Access

Introduction

Obtaining vascular access in infants and children can be difficult even under optimal conditions. Attempting emergent venous access in a hypotensive or struggling infant is even more challenging. However, the ability to perform this task in an expeditious manner is essential to resuscitation.

Routine Access

Careful consideration should be given to the routine sites for peripheral intravenous (IV) access before more emergent techniques are employed.

- Often access can be obtained via the peripheral veins on the back of the hand, in the antecubital space, or in the greater saphenous vein at the ankle.
- Common pitfalls in pediatric IV placement include attempting placement without sufficient assistance to adequately restrain the child, especially the involved extremity, and an inexperienced provider attempting to insert a catheter of insufficient size.
  - Infants can usually accept 22- and 24-gauge IV catheters, while toddlers' and young children's veins can accommodate 20- and 22-gauge catheters.
  - As an older child's size approaches adult size, the child is more likely to tolerate 16- and 18-gauge catheters.
- When timely attempts at routine peripheral access fail, consider external jugular venous cannulation or intraosseous (IO) needle placement. In an emergency, these alternatives, especially IO needle placement, should be performed within 2 minutes.

External Jugular Vein Cannulation

- The external jugular vein is a large peripheral vein that offers quick access to central circulation and is relatively easy to cannulate.
- It lies superficially along the lateral aspect of the neck, extending from the angle of the mandible downward until it pierces the deep fascia of the neck, just above the middle of the clavicle, ending in the subclavian vein. Because it is a very superficial vein, it tends to "roll" and be positional. Slight movement of the head may affect the flow of fluid.
- Technique
  - Position the patient in the supine, Trendelenburg position and rotate the head to the contralateral side. Position an infant at the edge of an examination table with the child's head lowered further (this is a 3-person technique).
  - Prepare the skin using an aseptic technique and position a sterile drape.
  - Apply digital pressure to the vein distally (just above the clavicle), which will often distend the vein (applying slight traction with the thumb at the proximal portion of the vein may prevent the vein from rolling).
  - Insert an IV catheter with an attached empty syringe into the center of the vein, keeping in mind its superficial position.
  - After puncturing the skin, aspirate on the syringe and, immediately upon seeing a flashback, advance the catheter into the lumen of the vein; stop if you meet resistance.
  - Secure the catheter to the skin using tape or a sterile adhesive dressing.
  - Maintaining the head in a neutral position will often optimize IV flow.
- Complications
  - Manipulation of the head in trauma patients with potential cervical spine injuries should be performed with appropriate caution.
  - Reduce the risk of air embolism by using a syringe attached to the angiocatheter during insertion.
  - Pneumothorax is a remote possibility.
  - Hematoma and vascular laceration are possible.

- If the carotid artery is punctured, remove the catheter and apply direct finger pressure.

Intraosseous Needle Placement

- IO needle placement can provide emergency vascular access in a child when peripheral access is unobtainable.
- When treating patients with cardiac arrest, IO placement should be considered the initial vascular access route.
- This technique can be used on patients of all ages and is preferred over the endotracheal route for administering emergency medications.
- The only emergency medication that cannot be administered via the IO route is Intralipid (Fresenius Kabi AG, Bad Homburg, Germany; indicated for local anesthetic cardiotoxicity [eg, lidocaine]).
- The bone marrow, a noncollapsible structure with a rich marrow venous plexus, can provide a rapid and reliable route for administering crystalloids, blood and blood products, vasopressors, and other drugs into the central circulation within seconds from the time of injection.
- Although products specifically designed for IO access are ideal, a styletted needle used for bone marrow aspiration or a large adult spinal needle can be used in an emergency.
- Technique
  - Common insertion sites (Figure 3-1):
    - Tibial plateau: the flat medial surface of the proximal tibia 1 to 2 cm below the tibial tuberosity.
    - Distal femur: 3 cm above the superior aspect of the patella.
    - Distal tibia, radius, and ulna; iliac crests; or sternum (use extreme caution if attempting insertion at this site in a young child).
  - Place the knee in approximately 30 degrees of flexion.
  - Apply rigid support to the posterior aspect of the insertion site (do not place your hand directly posterior to where the needle will be driven).
  - Using an aseptic technique, prepare the selected site with topical povidone iodine and chlorhexidine gluconate.

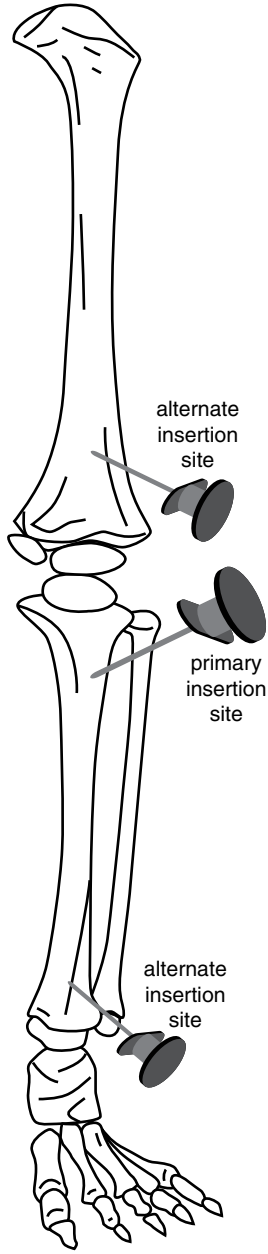


Figure 3-1. Preferred sites for intraosseous needle placement.

- In an awake patient, infiltrate the skin and subcutaneous tissue with local anesthetic.
- If using a product designed specifically for IO access, follow the manufacturer's directions.
- If using a bone marrow aspiration needle, after penetrating the skin, direct the IO needle at a slight angle (10°–15°) caudad (in the femur, angle it cephalad) and apply pressure with a to-and-fro rotary motion. Avoid "wobbling" the needle during insertion, which may result in needle fracture.
  - As the needle passes from the cortex of the bone into the marrow, resistance will diminish.
  - Remove the stylet and check needle placement by attaching tubing connected to a saline-filled, 10-mL syringe. The needle should stand securely in the bone without support.
  - Bone marrow can be aspirated and fluid should be easily infused.
- Blood withdrawn from the needle may be sent to the laboratory for basic testing, including a complete blood count, electrolytes, glucose, and the like.
- Observe for fluid infiltration of the calf; if this occurs, repeat the attempt in the opposite leg. If placement is unsuccessful, do not attempt again in the same extremity.
- Apply antibiotic ointment and a sterile dressing to the site and secure the tubing to the leg with sterile gauze.
- Minimize needle manipulation by attaching syringes or a stopcock to the tubing.
- Maintain vigilant care and observation of the insertion site; accidental dislodgement of an IO needle will manifest as fluid extravasation into a swollen calf, or the needle will be mobile at the site.
- Once the emergent condition has been addressed and the child has been resuscitated, attempt peripheral or central IV access, as IO lines are notoriously short lived (< 24 hours).

- Complications include:
  - osteomyelitis,
  - fracture (of bone or needle),
  - injury to the epiphyseal plate,

  - extravasation,
  - compartment syndrome,
  - hematoma, and
  - pressure necrosis of the skin.
- Contraindications include:
  - fractures or crush injuries near the insertion site,
  - fragile bone syndromes (eg, osteogenesis imperfecta), and
  - unsuccessful attempts in the same bone.

Percutaneous Central Venous Catheters

- Percutaneous central venous lines (see Table 3-1) may be required when peripheral venous access is either unavailable or insufficient. Central venous lines last longer (days to weeks), allow for central venous pressure monitoring and phlebotomy, and can safely tolerate vasoactive medication drips and hyperosmolar therapies.
- The preferred site for central vein access in children is the femoral vein.
  - It is easier and safer to access the femoral than the internal jugular or subclavian veins, especially during resuscitation.
  - Unlike in adults, there are no pediatric data suggesting a higher risk of infection at the femoral site.
- Lines placed under suboptimal conditions should be changed when the patient's condition warrants.
- Like adults, debilitated pediatric patients with indwelling central lines are at risk for catheter-related bloodstream infections and thrombosis. The risk of deep venous thrombosis is lower in children than in adults.
- The standard aseptic Seldinger technique is used for line placement. Remember the lateral to medial groin anatomy: NAVEL (nerve, artery, vein, empty space, lymphatics).

Peripheral Venous Cutdowns

- With increased use of the IO route, it is rarely necessary to cut down on a peripheral vein to obtain IV access.
- The preferred site is the long saphenous vein, just superior and anterior to the medial malleolus.

Table 3-1. Pediatric Central and Arterial Venous Line Sizes

Age/Size of Child	Central Line Sizes	Arterial Line Sizes
Infants < 5 kg	3 Fr 5–8 cm single lumen; 4 Fr 8-cm double lumen; **OR** 20-gauge 12-cm pediatric jugular vein kit	24-gauge IV catheter; 2.5 Fr 2.5 cm for peripheral (radial) access 2.5 Fr 5 cm for central (femoral) access
Larger infants/ toddlers < 10 kg	4 Fr 8-cm double lumen; **OR** 20-gauge 12-cm pediatric jugular vein kit	22- or 24-gauge IV catheter; 2.5 Fr 2.5 cm for peripheral (radial) access; 2.5 Fr 5 cm for central (femoral) access; **OR** 20-gauge 12–cm pediatric jugular vein kit for femoral access
Preschool children < 20–25 kg	5 Fr 8–12-cm double or triple lumen	20- or 22-gauge IV catheter
Older children	7 Fr adult triple lumen line	20- or 22-gauge IV catheter

Fr: French size

- Make a transverse skin incision, carry a blunt dissection down through the subcutaneous tissue, and directly cannulate the vein.

Intraarterial Catheters

- Arterial lines are placed in clinical situations when arterial blood pressure must be continuously measured (eg, when vasopressor agents are being administered), when frequent arterial blood gas or other blood sampling is necessary, and when cerebral perfusion pressure must be measured in patients with traumatic brain injury (see Table 3-1).
- The radial, dorsalis pedis, and posterior tibial arteries are the safest to use for an arterial line.

- Prior to placing a radial artery catheter, consider confirming that there is adequate collateral circulation to the hand via the ulnar artery by performing an Allen test.
- Complications (more commonly associated with axillary, brachial, and femoral sites) include:
  - distal ischemia,
  - thromboembolism, and
  - local infection.

Chapter 4

Mechanical Ventilation

Noninvasive Oxygen Delivery

- Practitioners need to be familiar with the benefits, limitations, and caveats of pediatric noninvasive and invasive oxygen delivery strategies.
- The choice of oxygen delivery device is based on the patient's needs, tolerance, and efficacy (Table 4-1).
- A nonrebreather mask must have at least 10 liters per minute (LPM) flow to prevent carbon dioxide (CO_2) retention and difficulty breathing with a tight mask.
- Blow-by oxygen is extremely imprecise and may lead to false reassurance of patient stability due to a potentially higher fraction of inspired oxygen (FiO_2) delivery than expected based on proximity of the patient to the delivery device.

Table 4-1. Oxygen Therapy Device Requirements

Device	FiO_2	Required Flow
Nasal cannula (low flow)	25%–40%	1–4 LPM
Nasal cannula (high flow)*	Variable	Infants: up 8 LPM Children: up to 40 LPM
Venturi mask	24%–40%	Variable
Simple face mask	35%–50%	6–10 LPM
Partial rebreather	50%–60%	10–12 LPM
Nonrebreather	90%–95%	10–15 LPM

FiO_2 = fraction of inspired oxygen
*Standard high-flow nasal cannula set-ups are both heated and humidified with titratable flow and FiO_2.

- Providers practicing in austere environments or on transports may be using oxygen supplied from a tank.

Table 4-2. Oxygen Tank Capacities

Tank	Max Volume	Conversion Factor
D	350 Liters	0.16
E	625 Liters	0.28
M	3,000 Liters	1.56
G	5,300 Liters	2.41
H/K	6,900 Liters	3.14

- Attention should be paid to available oxygen supply based on tank size, flow rates, and time requirements (Table 4-2).
- Available duration of flow can be calculated using the following formula:

$$D = \frac{k \times (P - R)}{F}$$

where D = duration of flow (min); k = conversion factor; P = tank pressure (PSI); R = safe residual pressure, usually 200 PSI; F = flow rate (LPM).

- For example, an E cylinder with 1,000 PSI running at 15 LPM will run out of oxygen in 33 minutes:

$$D = \frac{0.28 \times (2000 - 200)}{15} = 33.6 \text{ min}$$

Bag-Valve-Mask Ventilation

- A bag-valve mask (BVM), ideally with a positive end-expiratory pressure (PEEP) valve, should be used for the acutely decompensating patient.
- The appropriately sized mask will cover the child's mouth and nose and will sit below the eyes, across the bridge of the nose (Table 4-3).
- Excessive tidal volume delivery is very common in the manual ventilation of pediatric patients and care should be taken to use appropriately sized bags and limit compression volumes to appropriate chest rise (Table 4-4).
- A self-inflating bag:
  - Can be used without an oxygen source to deliver room air and up to 100% FiO_2 if an oxygen source and reservoir are used.

Table 4-3. Mask Sizes

Age	Size
Newborn	0–1
Infant	1
1–3 y	2
3–6 y	3
6–12 y	4
> 12 y	5

Table 4-4. Bag-Valve Sizes

Age	Size
Infant	500 cc
1–3 y	1 L
> 3 y	3 L

  - Can be used to achieve PEEP only if a PEEP valve is attached.
  - Will **not** provide passive oxygen flow (ie, blow-by oxygen) with most device types.
- A flow-inflating or anesthesia bag:
  - Requires an oxygen source to remain inflated and provide ventilation; it cannot be used without an oxygen source or if the oxygen source fails.
  - Provides PEEP by maintaining residual pressure in the bag during exhalation by manipulating the outlet control valve.
  - Is more complicated than the self-inflating bag and requires additional training and experience to use effectively.

Preparation for Mechanical Ventilation

- Prior to placing a pediatric patient on mechanical ventilation, ensure all equipment is available and appropriate for pediatrics. See Table 4-5 and Appendix C for a list of intubating equipment based on age and weight.

Table 4-5. Artificial Airways

Age	Endotracheal Tube Size	Tracheostomy Tube Size*
Newborn	3.0–3.5	3.0–3.5
6 mo	3.5	4.0
18 mo	3.5–4.0	4.0
24 mo	4.0–4.5	5.0
2–4 y	4.5–5.0	5.5
4–7 y	5.0–6.0	6.0
7–10 y	6.0–6.5	6–8
10–12 y	7.0	8.0

*Tracheostomy tube should typically be a half size larger than the appropriately sized ET tube.

- See Chapter 1, Basic Approach to Pediatric Trauma, for review of rapid sequence intubation procedures.
- Adequate BVM ventilation is much safer than attempting intubation and mechanical ventilation without appropriate equipment.
- Ensure that the available ventilator can deliver tidal volumes small enough for the patient's size (5–7 mL/kg) and ensure that a pediatric circuit is available, as inappropriately large volumes are lost in adult circuits.

Safety

- All ventilated patients should have an appropriately sized bag, mask, replacement endotracheal (ET) tube and stylet, or tracheostomy tube available at the bedside.
- Wall suction and a Yankauer airway suction device should also be available and functional at the bedside at all times.
- Most modern ventilators are capable of safely and effectively mechanically ventilating infants and small children, but providers should be aware of the lower limits of effective tidal volume delivery prior to connecting the patient to the circuit.
- A knowledgeable respiratory therapist should be able to adjust for these patients' special needs during setup.

Simplified Ventilation Modes

- All ventilator modes deliver either a set pressure (pressure control [PC]) or a set volume (volume control [VC]) for a set number of times per minute (R) to deliver a mandatory minute ventilation.
- The patient can take additional breaths that are either the same as the mandatory breaths (continuous mandatory ventilation [CMV]) or are size-controlled by the patient (intermittent mandatory ventilation [IMV]).
- In continuous spontaneous ventilation, no mandatory breaths are delivered and patients trigger and cycle all of their own breaths.
- Ventilator modes and equivalent terms
  - PC-CMV: ventilator and spontaneous breaths are given at set pressure; pressure assist/control (A/C), pressure control.

- VC-CMV: ventilator and spontaneous breaths are given at set volume; volume A/C, volume control.
- PC-IMV: ventilator breaths are given at set pressure, patient controls size of additional breaths; pressure-synchronized IMV.
- VC-IMV: ventilator breaths are given at set volume, patient controls size of additional breaths; volume-synchronized IMV.
- Continuous spontaneous ventilation: patient controls size of all breaths; spontaneous mode.

Initial Settings

- Initial ventilator settings depend on the patient's age, size, ventilator type, and selected mode (Table 4-6).

Table 4-6. Initial Pediatric Ventilator Settings

Setting	Level
Tidal volume	6–10 mL/kg
PIP	20–25 cm H_2O
PEEP	5 cm H_2O
R	Infants: 25–30 bpm
	Children: 15–25 bpm
	Adolescents: 10–15 bpm
I-time	Infant: 0.4–0.7 s
	Adolescent: 0.6–1 s
PS	10 cm H_2O
FiO_2	Begin at 1; rapidly wean to < 0.6

PIP = peak inspiratory pressure; PEEP = positive end-expiratory pressure; R = respiratory rate; bpm = breaths per minute; I-time = inspiratory time; PS = pressure support; FiO_2 = fraction of inspired oxygen

- The choice of ventilator mode is primarily based on provider comfort and familiarity; however, for severe or unilateral lung disease, consider initially using PC.
- When using PC modes:
  - If the BVM has an attached manometer, make note of the pressure required for good chest excursion.
  - Set this as the peak inspiratory pressure (PIP; remember, PIP = PC + PEEP); titrate for return tidal volume of 6 to 10 mL/kg.

- If using VC, tidal volume (Vt):
  - Initially, use 10 mL/kg, rounding down.
  - Look at chest rise, listen for breath sounds, and check PIP.
  - Decrease Vt if examination reveals excessive chest rise, large air entry, or higher-than-expected PIPs (< 30–35 cm H_2O).
- PEEP: Start at 5 cm H_2O for most patients, 10 cm H_2O or higher for pulmonary edema or pulmonary hemorrhage. Patients may require higher levels for atelectasis or severe hypoxemia.
  - Increase in increments of 2 cm H_2O.
  - Lung volume recruitment with PEEP takes hours but can be lost in minutes.
- Goal minute ventilation for infants is approximately 200 mL/kg/min and 100 mL/kg/min for adolescents.
- Measure arterial/venous blood gases to accurately assess oxygenation and ventilation status.
- Use chest radiographs to confirm the adequacy of ET tube placement and chest expansion.
- Use end-tidal CO_2 monitors if they are available.

Titration

- Goal Vt for patients with acute lung injury or acute respiratory distress syndrome should be around 6 mL/kg, and goal PIP should be less than 35 cm H_2O, with plateau pressure less than 30 cm H_2O, the same as for adults.
- Low Vt at high pressures are a sign of poor compliance. High Vt at low pressures indicate good compliance.
- FiO_2 greater than 50% for prolonged periods will cause oxidative damage; FiO_2 should be weaned to less than 60% as soon as possible.
- With severe lung disease, accept saturations down to 88%, pH levels down to 7.3, and grossly elevated partial pressure of carbon dioxide (pCO_2) to meet the above parameters and prevent ventilator-associated lung injury.
- Consider switching to a PC mode of ventilation for severe lung disease or for large air leaks due to small ET tube size or ineffective ventilation (eg, secondary to adult ventilator circuit on infant or small child). PC ventilation modes theoretically offer advantages by allowing effective Vt at lower PIP, and they improve oxygenation for any given Vt.

Hypercapnia

- CO_2 removal is dictated by minute ventilation (Vt × R). Adjust these parameters to improve ventilation. The ability to increase minute ventilation will be limited by high peak pressure and inadequate time for exhalation leading to breath stacking.
- Assuming stable clinical status with a fixed metabolic state and stable dead space/tidal volume ratio, adjustments can be made by the following equation:

$$Parameter_{New} = Parameter_{Current} \times \frac{CO_{2Current}}{CO_{2Goal}}$$

  where the parameter can be MV, Vt, or R when the patient does not compete with the ventilator.
- For example, a patient has an R set at 15 with a pCO_2 of 60. To reach a goal CO_2 of 40, the new rate should be 20 bpm:

$$RR_{New} = 15bpm \times \frac{60}{45} = 20\ bpm$$

- Always check a follow-up blood gas for large ventilator changes.

Moderate to Severe Hypoxemia

- Minimize air leak by placing a larger ET tube, repositioning head, or changing to pressure mode.
- Increase PEEP in increments of 2 cm H_2O to increase functional residual capacity (aerated lung volume); consider paralytics for PEEP greater than 10 cm H_2O.
- Increase I-time to improve oxygenation by increasing mean airway pressure.
- Increase rate, especially if pCO_2 is also elevated and minute ventilation needs to be increased.
- Changing to PC will result in improved oxygenation for the same volume delivered.
- Once the appropriate Vt is established, avoid changing or "weaning" volumes.
- In acute respiratory distress syndrome, ventilator-induced lung injury is associated with Vt greater than 8 to 10 mL/kg.

Inadequate Tidal Volume Delivery

- Increase Vt if examination reveals poor chest rise, minimal air entry, and lower-than-expected PIP (less than 15 cm H_2O).
- Adult-sized ventilator circuits may consume large amounts of volume each breath (2–3 mL for every cm H_2O difference between PIP and PEEP).
- If this occurs and no pediatric-sized circuit is available, increase Vt or change to a PC-style breath and monitor return minute ventilation (goal 100–200 mL/kg/min).

High Peak Pressures

- Suction ET tube.
- Check ET tube position with chest radiograph.
- Consider administering inhaled bronchodilators, especially if the patient exhibits wheezing or prolonged expiratory phase, or develops auto-PEEP.
- Changing to PC will result in lower peak pressure for the same Vt.
- Consider adopting a permissive hypercapnia strategy if lung compliance and oxygenation are poor in the face of high peak pressures.
  - Limit delivered Vt to roughly 6 mL/kg of ideal body weight.
  - Accept higher pCO_2 and lower O_2 saturations (> 88%).
  - Use higher PEEP and longer I-time for recruitment and oxygenation.
  - Most pediatric patients will tolerate a pH of up to 7.25.
  - Treat or minimize metabolic acidosis.

Problem Solving

- Review the **DOPE** pneumonic for potential causes of acute decompensation:
  - **D**islodged ET tube: check for equal breath sounds. Is end-tidal carbon dioxide waveform present?
  - **O**bstructed ET tube: suction mucous plug.
  - **P**neumothorax: check for equal breath sounds; use needle decompression or chest radiograph, depending on urgency.
  - **E**quipment failure: disconnect from circuit, hand bag, and confirm 100% oxygen is flowing.

Sedation Strategies for Ventilated Pediatric Patients

- **Postoperative short-term ventilation.** If the patient will be extubated in 6 to 12 hours, use:
  - Intermittent opioids, because pain will be the primary problem.
  - Intermittent benzodiazepines as needed for sedation.
  - A propofol drip, which can be considered for short-term sedation because it is titratable. Long-term propofol use (> 24–48 h) in pediatrics is discouraged given the concern for fatal metabolic acidosis.
- For **postoperative long-term ventilation,** use:
  - Continuous opioids to treat pain.
  - Intermittent or continuous-drip benzodiazepines as needed for sedation.
- For **medical short-term ventilation,** use:
  - Intermittent benzodiazepines because sedation is the primary requirement for ET tube tolerance.
  - Intermittent opioids may be needed.
- For **medical long-term ventilation,** use:
  - Continuous midazolam.
  - Continuous or intermittent opioids if needed for pain.

Remember, if the patient–ventilator synchrony is poor and adjustments to the ventilator are insufficient to make the patient comfortable, more sedation may be required.

Medications for Sedation

- **Midazolam:** starting dose is 0.05 to 0.1 mg/kg intravenous (IV); may repeat every 5 to 10 minutes until effective sedation is reached.
  - Use this as basis for a dosing schedule of IV every 1 to 2 hours.
  - If effective intermittent regimen cannot be easily established, consider continuous drip at (0.05–0.1 mg/kg/h); watch for respiratory depression and hypotension.
- **Lorazepam:** starting dose is 0.05 to 0.1 mg/kg IV.
  - May repeat in 5 to 10 minutes until effective sedation is reached.

  - Use this as a basis for an IV every 2 to 4 hours dosing schedule.
- **Morphine:** starting dose is 0.05 to 0.1 mg/kg IV.
  - Repeat dosing every 5 to 10 minutes until effective analgesia is established.
  - Use this as basis for an IV every 2 to 4 hour dosing schedule.
  - If effective intermittent regimen cannot be easily established, consider continuous drip.
- **Fentanyl:** starting dose is 0.5 to 1 μg/kg IV.
  - Repeat dosing every 5 to 10 minutes until effective analgesia is established.
  - Use this as a basis for an IV every 1 to 2 hour dosing schedule (see Chapter 2, Anesthesia, Table 2-3).

Considerations for Extubation

- Has lung disease improved? Use **SOAP** memory aid:
  - **S**ecretions/sedation/spontaneous Vt (> 5 mL/kg): What is the minimal suction frequency? Is the patient awake enough to breathe and protect airway?
  - **O**xygenation: FiO_2 less than 35%.
  - **A**irway: If a child has been ventilated for more than 48 hours or has been intubated several times, there is a significant risk of airway edema that may compromise a successful extubation. The presence of an audible air leak around the ET tube with the cuff deflated can be reassuring. Otherwise, consider starting airway dosing of dexamethasone 0.5 mg/kg/dose at least 12 hours prior to planned extubation, and continue every 6 hours for 4 to 6 doses.
  - **P**ressures: PIP less than 25 cm H_2O, PEEP less than 5 cm H_2O.

Predictors of Extubation Failure

- If a patient displays postextubation stridor, consider nebulized racemic epinephrine, heliox (if available), noninvasive positive-pressure ventilation, and steroids (Table 4-7).

Table 4-7. Predictors of Extubation Failure

Variable	Low Risk (< 10%)	High Risk (> 25%)
Vt (spontaneous)	≥ 6.5 mL/kg	≤ 3.5 mL/kg
FiO_2	≤ 0.30	> 0.40
PIP	≤ 25 cm H_2O	≥ 30 cm H_2O

FiO_2: fraction of inspired oxygen; PIP: peak inspiratory pressure; Vt: tidal volume
Data sources: (1) Venkataraman ST, Khan N, Brown A. Validation of predictors of extubation success and failure in mechanically ventilated infants and children. *Crit Care Med*. 2000 Aug;28(8):2991–2996. (2) Khan N, Brown A, Venkataraman ST. Predictors of extubation success and failure in mechanically ventilated infants and children. *Crit Care Med*. 1996 Sep;24(9):1568–1579.

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Chapter 5

Transfusion Medicine

Introduction

- Indications for transfusion in children are no different than for adults, though blood products should not be transfused on a unit basis; weight-based considerations are necessary.
- If transfusing less than a "unit" dose, consider having the blood bank "split" a unit and reserve the remainder to avoid unnecessary multiple donor exposure.
- Estimated blood product unit volumes currently in theater:
  - Packed red blood cells (PRBCs): 300 to 350 mL/unit.
  - Whole blood: 450 to 500 mL/unit.
  - Fresh frozen plasma (FFP): 250 to 300 mL/unit.
  - Platelets:
    - Apheresis, single-donor: 250 to 300 mL/unit.
    - Concentrate, random-donor: 50 mL/unit.
  - Cryoprecipitate: 10 to 15 mL/unit.

Packed Red Blood Cell Transfusion

- Indications: hemoglobin (Hgb) less than 7 g/dL, symptomatic anemia with Hgb 7 to 10 g/dL or hemorrhage.
- Administer 10 to 15 mL/kg over 4 hours (≤ 2.5 mL/kg/h) for routine use. This will usually increase Hgb by 2 to 3 g/dL and hematocrit (HCT) by 6% to 9% in a stable patient.
- To estimate the volume of PRBC to transfuse:

Volume of PRBC:

$$\frac{\text{EBV} \times (\text{desired HCT} - \text{present HCT})}{\text{HCT of PRBC}}$$

where EBV is the estimated blood volume (Table 5-1), and the approximate HCT of PRBC is 55% to 60%.

Table 5-1. Blood Volume by Age

Age	Blood Volume (mL/kg)
Premature neonate	100
Full-term neonate	85
Older infant	75
> 12 months	70–75

- Give smaller amounts for anemia, which is suspected to be chronic in nature, to avoid volume overload. As a general rule, give *X* mL/kg, where *X* is the patient's Hgb g/dL (eg, if Hgb is 5 g/dL, give 5 mL/kg PRBCs over 4 hours).
- Risks of PRBC transfusions are similar to those in adults and include infection, transfusion reactions (ie, febrile nonhemolytic, acute hemolytic, anaphylactic, delayed hemolytic, urticarial), volume overload (transfusion-related cardiac overload), and transfusion-related acute lung injury. See discussion on massive transfusions below for unique complications.
- Administration of PRBCs in storage longer than 14 days has been associated with increased morbidity and mortality in critically ill patients (eg, hyperkalemic cardiac arrest).
- Frozen blood may be available, but must first be deglycerolized before use. It is then administered like a standard PRBC transfusion. It can be considered a "fresh" unit, since it was frozen within 6 days of being collected. See Joint Theater Trauma System Clinical Practice Guidelines, *Frozen and Deglycerolized Red Blood Cells* (http://www.usaisr.amedd.army.mil/assets/cpgs/Frozen_Blood_2_Apr_12.pdf).

Whole Blood Transfusion

- Whole blood transfusion is indicated in cases when massive transfusion (MT) is required and when there is a need for a component product that is unavailable (frequently platelets).
- Administration: initial volume of 10 to 15 mL/kg can be given quickly or over a 4-hour period, depending on the situation.

Fresh Frozen Plasma

- Indications for FFP include massive transfusion, coagulopathy and bleeding, disseminated intravascular anticoagulation, and prolonged *R* value on thromboelastography (TEG).
- FFP contains all coagulation factors except platelets.
- Avoid using FFP in critically ill patients with simple coagulopathy without clinical bleeding.
- Thawed plasma can be refrigerated at 1°C to 6°C for up to 5 days.
- Administer an initial volume of 10 to 15 mL/kg.
- Routine FFP transfusion rates should not exceed 1 mL/kg/min, as this may precipitate hypocalcemia, hypotension, severe cardiac depression, and cardiac arrest.
- Risks are the same as for PRBCs and hypocalcemia.

Platelets

- Indications include massive transfusion, thrombocytopenia, and bleeding, or, prior to invasive procedure, decreased maximum amplitude on TEG (see Bolliger, et al, in Further Reading).
- Avoid use in nonbleeding, critically ill patients with platelet values greater than 20,000/μL.
- Apheresis platelet units contain both plasma and platelets.
- Administer an initial volume of 10 mL/kg; alternatively, for platelet concentrates, give 1 unit (or "one pack") for every 5 kg body weight. Infuse over 30 minutes, no longer than 2 hours. For infants and children, these estimates should increase the platelet count by approximately 50,000/μL.
- Risks: same as for PRBCs, though there is an approximately 15-fold higher risk of infection than for PRBCs given from room temperature storage.

Cryoprecipitate

- Indications include MT, coagulopathy and bleeding, and decreased alpha-angle on TEG.
- Cryoprecipitate is a source of fibrinogen, factor VIII, factor XIII, and von Willebrand's factor; each unit contains a minimum of approximately 250 mg of fibrinogen and 80 international units of factor VIII.

- Administering 1 unit for every 5 kg body weight should raise the fibrinogen level by 60 to 100 mg/dL in a stable patient.

Special Blood Product Preparations

- All blood products should be infused using a standard blood filter (170–260 μm) that removes microaggregates.
- Blood filters are not the same as leukocyte reduction filters.
- Leukocyte reduction
  - Most blood products are leukoreduced at the time of collection to prevent febrile, nonhemolytic transfusion reactions.
  - If not done prior to storage, leukocyte reduction may be done at the bedside only for PRBCs and platelets using product-specific leukocyte filters during the transfusion.
  - Leukocyte reduction can decrease the risk of cytomegalovirus (CMV) transmission and human leukocyte antigen alloimmunization.
  - Leukocyte reduction will dramatically slow the rate of a transfusion and may not be appropriate during a transfusion for hemorrhagic shock because of active bleeding.
- Irradiation
  - Leukocyte reduction does not eliminate all donor lymphocytes. Irradiation of blood products stops proliferation of donor lymphocytes that may otherwise trigger transfusion-associated graft-versus-host disease.
  - Irradiation does not kill viruses.
  - Irradiation is recommended for transfusions in premature infants and children with either congenital or acquired immunodeficiency.
- CMV-safe products
  - For premature infants and children with congenital or acquired immunodeficiency, CMV-seronegative blood products are preferred.
  - Leukocyte reduction reduces the risk of viral transmission. If CMV-negative products are unavailable, leukocyte reduction is a safe alternative.

Massive Transfusion in Children

- The same principles of "damage control resuscitation" or "hemostatic resuscitation" that apply to adults can be applied to children.
- Transfusion in a pediatric patient can be considered an MT when half or more of the circulating blood volume, or 40 mL/kg or more, is replaced in under 24 hours.
- The following clinical parameters may predict the need for a bleeding child receiving an MT:
  - severe tachycardia or hypotension for age,
  - base deficit greater than 5 mEq/L,
  - lactate greater than 4 mmol/L,
  - international normalized ratio greater than 1.5, and
  - hemoglobin at admission less than 9 g/dL.
- Use of a rapid infuser (eg, Belmont [Belmont Instrument Corporation, Billerica, MA]) should be avoided in small children.
  - Instead, use multiple smaller syringes, or set up a "pull-push" system with a 3-way stopcock.
  - Smaller syringes are also more useful in pushing blood through small IVs (eg, 22- and 24-gauge).
- See Sample Massive Transfusion Protocol (Table 5-2) for a suggested strategy of administering blood products (also see Edwards, et al, and Diab, et al, in Further Reading).

Massive Transfusion Adjuncts

- Tranexamic acid (TXA) is an antifibrinolytic that has some mortality benefit in adult and pediatric trauma patients with documented hyperfibrinolysis.
  - Indicated when the injury is less than 3 hours old or LY30 is greater than 7.5% on TEG.
  - Adult dose: 1 g IV load followed by 1 g IV infusion over 8 h.
  - Optimal dosing and timing have not been established in pediatrics due to limited data. The literature supports a loading dose of 10 to 15 mg/kg (max 1 g) diluted in normal saline and given over 10 minutes.
  - Follow up with a maintenance infusion of 1 mg/kg/h for 8 hours.

Table 5-2. Sample Massive Transfusion Protocol

Packages to Transfuse in Order	0–4 kg Neonate	5–9 kg Infant	10–24 kg Young Child	25–49 kg Older Child	≥ 50 kg Adult
Emergency Release (A)	RBC	1 RBC	2 RBC	3 RBC	5 RBC
B	½ RBC	1 RBC	2 RBC	3 RBC	5 RBC
	½ FFP	1 FFP	2 FFP	3 FFP	5 FFP
	½ aPlt	½ aPlt	1 aPlt	1 aPlt	1 aPlt
C	½ RBC	1 RBC	2 RBC	3 RBC	5 RBC
	½ FFP	1 FFP	2 FFP	3 FFP	5 FFP
	2 Cryo	3 Cryo	4 Cryo	6 Cryo	8 Cryo
B	½ RBC	1 RBC	2 RBC	3 RBC	5 RBC
	½ FFP	1 FFP	2 FFP	3 FFP	5 FFP
	½ aPlt	½ aPlt	1 aPlt	1 aPlt	1 aPlt
C	½ RBC	1 RBC	2 RBC	3 RBC	5 RBC
	½ FFP	1 FFP	2 FFP	3 FFP	5 FFP
	2 Cryo	3 Cryo	4 Cryo	6 Cryo	8 Cryo
B	½ RBC	1 RBC	2 RBC	3 RBC	5 RBC
	½ FFP	1 FFP	2 FFP	3 FFP	5 FFP
	½ aPlt	½ aPlt	1 aPlt	1 aPlt	1 aPlt
C	½ RBC	1 RBC	2 RBC	3 RBC	5 RBC
	½ FFP	1 FFP	2 FFP	3 FFP	5 FFP
	2 Cryo	3 Cryo	4 Cryo	6 Cryo	8 Cryo

aPlt: apheresed platelets
Cryo: cryoprecipitate
FFP: fresh frozen plasma
RBC: red blood cells
Adapted with permission from Naomi Luban and Children's National Medical Center. Literature review and protocol developed by Wong E, Criss V, Pary P, and Luban N. June 2, 2014.

- TXA may cause thrombotic complications; it is not recommended if there is renal impairment or upper urinary tract bleeding. Discontinue treatment if changes in vision occur. See Napolitano LM, et al; Eckert MJ, et al; and Royal College of Paediatrics and Child Health, in Further Reading.
- TXA is contraindicated with subarachnoid hemorrhage and active thromboembolic disease (pulmonary embolism, deep vein thrombosis, cerebral thrombosis).

- Recombinant factor VIIa has not shown a clear benefit in adult trauma; its current use is controversial.
  - Recombinant factor VIIa will **NOT** be effective if the patient has low fibrinogen (< 100 g/dL), has thrombocytopenia (< 100 K/mm^3), or is acidotic (pH < 7.2).
  - Dosing: 90 μg/kg IV.

Risks of Massive Transfusion

- Hyperkalemia
  - Cardiac arrest due to hyperkalemia has been reported secondary to pediatric MT; risk factors include:
    - younger age (more common in neonates and infants);
    - faster rate of infusion, more so than total volume; and
    - central venous administration, likely due to dilution effect of potassium when given peripherally.
  - During pediatric MT, monitor telemetry and measure serial electrolytes (particularly for acidosis and hypocalcemia), which may exacerbate intravascular hyperkalemia.
  - Risk may be reduced by using "fresh" PRBCs less than 7 days old and by transfusing through a large-bore peripheral IV (> 23 gauge) rather than a central line.
  - See Chapter 25, Basic Fluid and Electrolytes, for hyperkalemia management.
- Hypocalcemia
  - Citrate-containing blood products (especially FFP) decrease the ionized calcium level and can cause significant hypotension in children, especially infants.
  - Treat with IV calcium chloride (10–20 mg/kg) or calcium gluconate (60–100 mg/kg) for ionized calcium level less than 1 mmol/L. Consider empiric treatment if giving the patient large amounts for MT or rapid plasma infusion.
- Hypomagnesemia
  - Hypomagnesemia is caused by same mechanism as in hypocalcemia; it also directly contributes to secondary hypocalcemia.
  - Treat with magnesium sulfate 25 to 50 mg/kg IV; give slowly, no faster than 20 to 30 minutes, watching for hypotension. Maximum dose is 2 g.

- Hypothermia
  - There is higher risk of hypothermia in children given their larger body-surface-area-to-weight ratio.
  - Hypothermia exacerbates the acute coagulopathy of trauma.
  - It is mitigated by use of blood warmer as in adults.
- Transfusion-Associated Volume Overload
  - Transfusion-associated volume overload is caused by overshooting resuscitation or by transfusions in stable patients with chronic anemia.
  - It is manifested by pulmonary edema, gallop rhythm, hepatomegaly, and jugular venous distention.
  - Use slow transfusion rates for patients with chronic anemia.
  - Consider using furosemide (0.25–0.5 mg/kg IV) midtransfusion or after transfusion.

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Chapter 6

Hemodynamics and Shock

Shock is characterized by inadequate systemic tissue perfusion and oxygen delivery; if left untreated, subsequent cellular and metabolic derangement leads to end-organ dysfunction, failure, and death. A basic understanding of pediatric vital signs is needed to accurately perform hemodynamic monitoring and assess for shock (see Chapter 1, Basic Approach to Pediatric Trauma, Table 1-1).

Recognizing Shock

According to the American Heart Association's Pediatric Advanced Life Support course, the spectrum of shock is characterized as follows:

- Compensated shock: physiologic compensation maintains blood flow to vital organs through tachycardia and vasoconstriction, preserving a normal blood pressure. Clinical signs include:
  - fever or hypothermia,
  - tachycardia,
  - mottled or cool extremities,
  - weak peripheral pulses,
  - delayed capillary refill (central longer than 2 s, peripheral longer than 3 s),
  - irritability,
  - oliguria, and
  - lactic acidosis.
- Decompensated shock: compensatory mechanisms fail, systemic signs of inadequate end-organ perfusion develop, and hypotension ensues. Clinical signs include:
  - hypotension, a late finding, is defined as a systolic blood pressure in the different age groups as follows:

    - Infants younger than 1 month old: less than 60 mmHg.
    - Infants 1 to 12 months old: less than 70 mmHg.
    - Children 1 to 10 years old: less than 70 mmHg + 2(age [in years]).
  - altered mental status;
  - acute respiratory distress syndrome;
  - hepatic dysfunction;
  - acute kidney injury; and
  - coagulopathy.
- Irreversible shock: all compensatory mechanisms are exhausted and multisystem organ failure ensues; tachycardia and tachypnea may progress to bradycardia and apnea, cardiac arrest, and death.

Types of Shock

There are three broad mechanisms of shock; a patient may have shock as a result of more than one cause.

- Hypovolemic shock is the most common cause of shock. It results from extravascular (eg, diarrhea, emesis, osmotic diuresis, burns) or intravascular (eg, hemorrhage) fluid losses (Table 6–1).
- Cardiogenic shock results from inadequate cardiac output.
  - Cardiogenic shock is most commonly due to cardiomyopathies, arrhythmias, or obstructive disorders, such as tension pneumothorax or cardiac tamponade.
  - In neonates, unrecognized ductal-dependent congenital heart disease (ie, coarctation of the aorta, interrupted aortic arch, aortic stenosis, hypoplastic left heart syndrome, and transposition of the great arteries) may present with cardiogenic shock in the first few days to weeks of life at the time of functional ductus arteriosus closure.
- Distributive shock results from systemic vasodilation and decreased systemic vascular resistance due to septic, neurogenic, and anaphylactic shock.
- Many other conditions can also lead to shock through these mechanisms, including bowel obstruction, pneumonia, diabetic ketoacidosis, neglect, cystic fibrosis, and inborn errors of metabolism.

Table 6-1. Assessing the Severity of Hypovolemic Shock*

Level	Weight Lost (Infant)	Weight Lost (Child)	Signs and Symptoms
Mild	5%	3%	Decreased urinary output, mild tachycardia, dry mucous membranes, decreased tearing
Moderate	10%	6%	Oliguria, tachycardia, dry membranes and tongue, sunken eyes and fontanelle, poor skin turgor, borderline to poor perfusion, mild to moderate tachypnea, possible shock
Severe	15%	9%	Oliguria or anuria, possible shock, poor perfusion, decreased LOC, tachypnea, marked metabolic acidosis, shock

*Percentages indicate actual weight loss from water loss or deficit.
LOC: level of consciousness

- In addition to available history (eg, infection, trauma, toxin/allergen exposure, congenital heart disease), clinical examination may aid in the distinction of different shock etiologies (Table 6-2).
  - Cardiac output can be assessed by observing heart rate, capillary refill time, mental status, and urine output.
  - Preload can be assessed by observing changes in liver span or by viewing heart size with a chest radiograph.

Table 6-2. Distinguishing Features of Clinical Shock States

	Physical				Monitoring		
Scenario	**WOB**	**CRT**	**Liver**	**Skin**	**CVP***	**SVR**	**CI**
Hypovolemic	nl	> 2	nl	Cool	↓	↑	↓
Cardiogenic	+++	> 2	+++	Cool	↑	↑	↓
Distributive	+/++	+/–	nl	+/-	↓	↓↑	↓↑

*Normal CVP for infants and children is 5–8 mmHg.
CI: cardiac index; CRT: capillary refill time; CVP: central venous pressure; nl: normal; SVR: systemic vascular resistance; WOB: work of breathing

- Systemic vascular resistance can be assessed by capillary refill time, pulse pressure, and by comparing differential skin temperatures (peripheral to central).

Goal-Directed Therapies

The treatment of shock in pediatric patients is time-based, goal-directed (Figure 6-1), and targets the initial therapeutic outcomes as recommended by the Surviving Sepsis Campaign 2012 (see Further Reading), including:

- capillary refill: 2 seconds or less;
- normal blood pressure for age;
- normalized pulses, with peripheral pulses equal to central pulses;
- warm extremities;
- urinary output greater than 1 mL/kg/h; and
- normalized mental status.

- After the initial resuscitation, if central vascular pressure monitoring is available, target:
  - central venous oxygen saturation greater than 70%, and
  - cardiac index of 3.3 to 6.0 L/min/m^2.
- For respiratory distress and hypoxemia, apply supplemental oxygen via facemask. If available, consider initiating high-flow nasal cannula or nasopharyngeal continuous positive airway pressure.
- If respiratory failure is imminent, early intubation and mechanical ventilation may be indicated (see Chapter 1, Basic Approach to Pediatric Trauma, and Chapter 4, Mechanical Ventilation, for further information).
- Early establishment of vascular access, fluid resuscitation, and inotropic support prior to intubation may blunt hemodynamic collapse during initiation of positive pressure ventilation.
- During rapid sequence intubation of the pediatric shock patient, it is critical to avoid sedation with medications that may worsen hemodynamics.
  - Ketamine is preferred for induction in septic shock, as long as it is not contraindicated (suspected increased ICP).
  - Etomidate is an acceptable choice for hypovolemic or cardiogenic shock, though it should be avoided in septic shock.

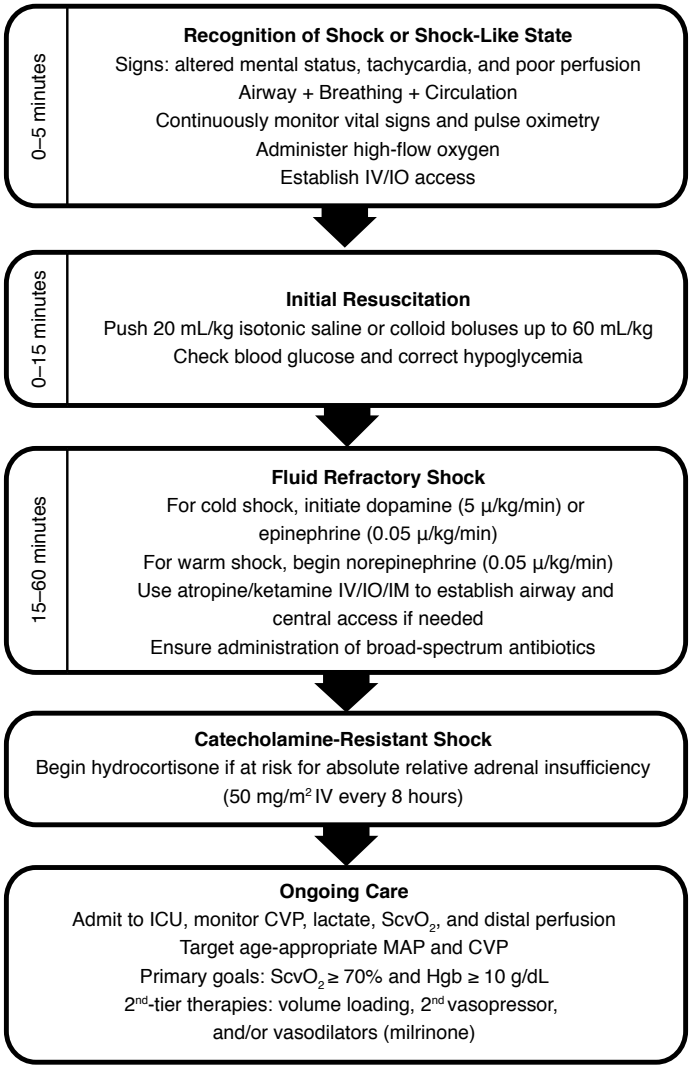


Figure 6-1. Goal-directed algorithm for hemodynamic support of infants and children.

CVP: central venous pressure
Hgb: hemoglobin
ICU: intensive care unit
IM: intramuscular
IO: intraosseous
IV: intravenous
MAP: mean arterial pressure
$ScvO_2$: central venous oxygen saturation

  - If etomidate is used, adrenal insufficiency should be considered and evaluated by measuring serum cortisol levels if available.
- Establish intravenous access, ideally in two locations; if vascular access is insufficient, early placement of intraosseous access is recommended (see Chapter 3, Vascular Access). Intraosseous access is functionally equivalent to central venous access; all drugs and products given via a central line can be given via an intraosseous line.
- Administer rapid volume expansion with normal saline or lactated Ringer's solution in boluses of 20 mL/kg over 5 to 10 minutes, then reassess.
  - Reassessment includes evaluating level of consciousness and ensuring tachycardia and hypotension have reversed, urine output has increased, and capillary refill and peripheral pulses have normalized.
  - Evidence of rales or hepatomegaly on examination suggests that inotropes be used if further resuscitation is necessary.
  - If anemia is evident at presentation due to hemorrhage or hemolysis, early initiation of transfusion is recommended.
  - During acute resuscitation of septic shock, a hemoglobin of 10 g/dL or more is targeted; once stabilized, a restrictive transfusion threshold target of 7 g/dL or more should be followed.
- If there is no improvement after the initial bolus, repeat boluses as indicated, up to 60 mL/kg total within the first 15 to 30 minutes.
- In septic shock, broad-spectrum antibiotics against endemic and epidemic pathogens should be administered within an hour of presentation (see Chapter 29, Infectious Diseases, and Table 29-1 specifically for empiric antibiotic choices by age).
  - Blood cultures should be obtained prior to administering antibiotics if possible, though antibiotics should not be delayed to do so.
  - Clindamycin should be added for toxic shock syndrome with unresponsive hypotension to inhibit toxin production.
  - Antibiotics may be given orally or intramuscularly if parenteral access is not available (see Chapter 29, Infectious Diseases, Tables 29-2 and 29-3).

Table 6-3. Vasoactive Support

Drug/Indication	Dosing	Effects	Action	Comments
Dopamine Septic shock Cardiogenic shock	Start at 5 μg/kg/min; range 2–20 μg/kg/min	β 5–10 μg/kg/min α > 15 μg/kg/min	Acts indirectly via NE release; inotrope, chronotrope, vasopressor	Give centrally if possible; not as effective in neonates who have limited NE stores
Dobutamine Cardiogenic shock	Start at 5 μg/kg/min; range 2–20 μg/kg/ min	β	Direct-acting pure inotrope, lusitrope (diastolic relaxation)	May result in peripheral vasorelaxation and tachycardia
Epinephrine Postarrest shock Cold "septic" shock	Start at 0.05 μg/kg/ min; range 0.05–1 μg/kg/min	β at low doses α at higher doses	Direct-acting inotrope, chronotrope, and potent vasopressor	Give centrally if possible; may cause organ ischemia at high doses
Norepinephrine Warm septic shock	0.05–2 μg/kg/min	α:β 3:1	Direct-acting potent vasopressor	Give centrally if possible; may cause organ ischemia
Phenylephrine Spinal shock Septic shock	0.05–2 μg/kg/min	Pure α	Direct-acting potent vasopressor	Give centrally (burns)
Milrinone ↑ PVR or SVR with cardiac dysfunction	0.2–1 μg/kg/min; Loading dose 50 μg/kg over 10–60 minutes	Phosphodiesterase inhibition (↑ cAMP)	Inotrope and vasodilator, lusitrope (diastolic relaxation)	Thrombocytopenia, $T_{1/2}$ h vs min Dose adjustment needed in renal impairment
Nitroprusside Hypertension or ↑ SVR states	0.5–5 μg/kg/min	Exogenous NO donor	Potent arteriolar vasodilator	Need arterial line to watch BP; cyanide toxicity

BP: blood pressure; cAMP: cyclic adenosine monophosphate; NE: norepinephrine; NO: nitric oxide; PVR: pulmonary vascular resistance; SVR: systemic vascular resistance

- Peripheral inotropic support with dopamine should be added until central venous access is obtained if fluid resuscitation fails to reverse septic shock within the first hour (Table 6-3).
  - Add epinephrine for cold shock (myocardial depression, capillary leak, metabolic acidosis, cool and mottled extremities).
  - Add norepinephrine for warm shock (increased carbon dioxide, bounding pulses, decreased systemic vascular resistance, warm extremities, normal or extremely fast capillary refill time, wide pulse pressures).
- For patients with low cardiac output, elevated systemic vascular resistance, and normal blood pressure, consider adding vasodilator therapies, such as milrinone, as well as inotropes.
- Correct metabolic and electrolyte disturbances, such as hypoglycemia and hypocalcemia.
- For patients with fluid and catecholamine-resistant shock or documented absolute adrenal insufficiency, give stress-dose steroids (hydrocortisone, 50 mg/m^2/day).
- For neonates (less than 1 month old) presenting in shock, begin prostaglandin infusion until a ductal-dependent cardiac lesion is ruled out (see Chapter 26, Respiratory Emergencies, and Chapter 27, Cardiology, for more information).
- Once perfusion has been normalized, continue to treat hypovolemic shock by calculating replacement fluids based on the estimated deficit (percent dehydration, see Table 6-1), ongoing losses, maintenance needs, and special situations (eg, hypernatremia or hyponatremia).

Further Reading

1. Dellinger RP, Levy MM, Rhodes A, et al. Surviving sepsis campaign: international guidelines for management of severe sepsis and septic shock: 2012. *Crit Care Med*. 2013 Feb;41(2):580–637.

Chapter 7

Managing Intracranial Pressure

Elevated intracranial pressure (ICP) may be difficult to diagnose and is associated with both poor neurologic outcome and increased mortality in infants and young children. Early recognition of elevated ICP and rapid intervention are key in maximizing positive outcomes in pediatric trauma.

Etiologies of Increased Intracranial Pressure

- Encephalitis
- Head trauma (accidental or abusive)
- Hydrocephalus
- Hemorrhage
- Intracranial mass lesion
- Meningitis
- Status epilepticus
- Stroke
- Shock leading to hypoxic-ischemic encephalopathy

Initial Evaluation

- Evaluate airway, breathing, and circulation (ABCs).
  - Ensure adequate ventilation and oxygenation.
  - Rapid sequence induction/intubation therapy may be necessary if airway protection is needed (eg, Glasgow Coma Scale score ≤ 8).
  - Blood pressure (BP) management depends on etiology, but if the patient is hypertensive due to elevated ICP, do not lower the patient's BP; doing so may reduce the cerebral perfusion pressure (CPP).
    - CPP is calculated as:

$$CPP = MAP - ICP$$

Where mean arterial pressure (MAP) is defined as:

$$MAP = \frac{systolic\ BP + 2(diastolic\ BP)}{3}$$

- Perform a neurological assessment.
  - Use a modified Glasgow Coma Scale (see Chapter 1, Basic Approach to Pediatric Trauma, Table 1-3) for infants and children.
  - Assess for signs of elevated ICP and herniation (Table 7-1).
- Treat critical elevations in ICP (Figure 7-1).
- Obtain head imaging with computed tomography or magnetic resonance imaging, if available.
- Consider ICP monitoring.

Table 7-1. Signs of Increased Intracranial Pressure

	Acute Increased ICP	Chronic Increased ICP
Infants	Irritability Poor feeding/vomiting Split sutures Bulging fontanelle Altered mental status Upgaze paresis	Irritability Poor feeding/vomiting Increased head circumference Bulging fontanelle Developmental arrest or regression Upgaze paresis
Children	Severe, acute headache Seizures Vomiting Rapidly deteriorating mental status Posturing Focal neurologic deficits Papilledema Pupillary abnormalities Cushing's triad*	Chronic, progressive headache Seizures Early morning vomiting Change in school performance Altered mental status 6th cranial nerve palsy Focal neurologic deficits Papilledema Visual changes

ICP: intracranial pressure
*Hypertension, bradycardia, deep and slow respirations (occurs shortly before herniation).
Data source: Point-of-Care Quick Reference: Increased Intracranial Pressure. Elk Grove Village, IL: American Academy of Pediatrics, 2014. http:// www.pediatriccareonline.org/pco/ub/view/Point-of-Care-Quick-Reference. Accessed June 10, 2014.

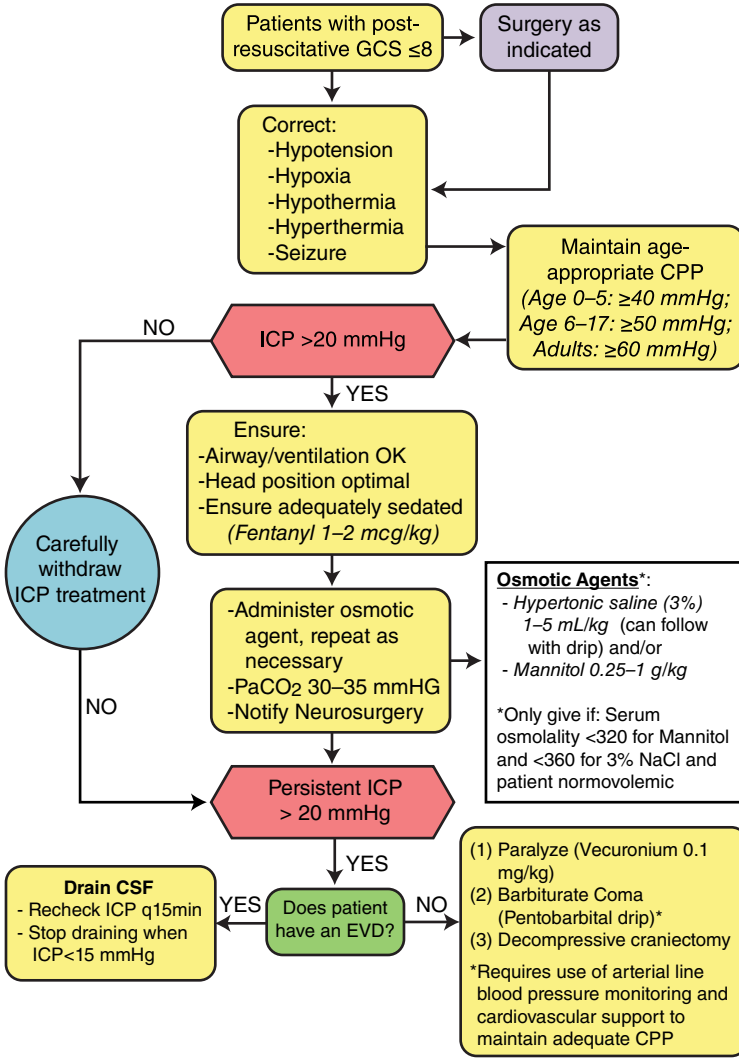


Figure 7-1. Algorithm for managing acute intracranial hypertension.
CPP: cerebral perfusion pressure
EVD: extraventricular drain
GCS: Glasgow Coma Scale
ICP: intracranial pressure
$PaCO_2$: partial pressure of carbon dioxide in blood

Indications for Monitoring Intracranial Pressure

- Monitoring ICP in infants and children with severe traumatic brain injury and Glasgow Coma Scale scores greater than or equal to 8 is recommended.
- ICP monitoring may also be considered in children who are at risk for neurologic deterioration as a result of traumatic mass lesions or in whom serial neurologic examinations are precluded by sedation, neuromuscular blockade, or anesthesia.

Neurologic Intensive Care Monitoring

- In addition to ICP monitoring (see Chapter 13, Neurosurgery), brain-injured patients should also be monitored for:
  - ventilation, including capnography (avoid hyper/hypoventilation);
  - oxygenation, including pulse oximetry (avoid hypoxia);
  - electrocardiogram;
  - vitals (heart rate, BP, temperature; avoid hyperthermia);
  - blood glucose (avoid hypoglycemia); and
  - fluid intake and output (with a central venous catheter to evaluate volume status and a Foley catheter for urine output).

Treatment

- Assess and maintain ABCs.
  - Rapid sequence induction/intubation therapy may be necessary if airway protection is needed (eg, Glasgow Coma Scale score ≤ 8).
- Maintain age-appropriate CPP goal:
  - Age 0–5: CPP 40 mmHg or greater.
  - Age 6–17: CPP 50 mmHg or greater.
  - Adults: CPP 60 mmHg or greater.
- CPP can be reduced as a result of increased ICP, decreased BP, or both.
- Autoregulation usually maintains normal cerebral blood flow and CPP, but this process can be impaired in brain injury such that cerebral blood flow passively follows changes in CPP.
- Overall goals (Table 7-2):
  - Maintain ICP less than 20 mmHg.
  - Maintain CPP above goal according to age.

Table 7-2. Pediatric Traumatic Brain Injury Management Goals

Systems	Management Goals
Respiratory	• Early tracheal intubation if GCS ≤ 8 • Avoid hypoxemia, maintain SaO_2 > 97%, PaO_2 > 80 mmHg • Maintain $PaCO_2$ 35–40 mmHg • Hyperventilation ($PaCO_2$ 30–35 mmHg) if impending herniation ° Avoid prophylactic severe hyperventilation ($PaCO_2$ < 30 mmHg)
CV	• Avoid hypotension: maintain SBP > [(2 × age) + 70 mmHg] • Replace intravascular volume ° Avoid hypotonic and glucose-containing solutions • Vasopressor agents as needed to maintain CPP
CNS	• Monitor ICP and avoid ICP > 20 mmHg • Maintain CPP appropriate for age • Adequate sedation and analgesia °Avoid continuous infusion of propofol • Hyperosmolar therapy ° Maintain Na^+ 140–155 and P_{osm} < 360 mOsm/L • Establish therapeutic CSF drainage (EVD) • Treat seizures ° Consider prophylactic fosphenytoin for severe TBI • Barbiturate coma and decompressive craniectomy are reserved for elevated ICP refractory to standard medical care
Metabolic	• Prevent hypoglycemia and severe hyperglycemia ° Monitor blood glucose q4h ° Avoid exogenous glucose × 48 h unless glucose < 70 mg/dL • Avoid hyperthermia and maintain normothermia • Control shivering in intubated patients with neuromuscular blockade (eg, vecuronium)

CNS: central nervous system
CPP: cerebral perfusion pressure
CSF: cerebrospinal fluid
CV: cardiovascular
EVD: extraventricular drain
GCS: Glasgow Coma Scale
ICP: intracranial pressure
$PaCO_2$: partial pressure of carbon dioxide in blood
PaO_2: partial pressure of oxygen in blood
P_{osm}: plasma osmolality
SaO_2: oxygen saturation
SBP: systolic blood pressure
TBI: traumatic brain injury

Data source: Dinsmore J. Traumatic brain injury: an evidence-based review of management. *Contin Educ Anaesth Crit Care Pain*. 2013:13(6):189–195.

- Avoid factors that aggravate or precipitate elevated ICP, such as:
  - obstruction of venous return (keep head midline, elevate the head of bed to 30°, and avoid agitation),
  - respiratory problems (hypoxemia, hypercapnia),
  - fever,
  - severe hypertension,
  - hyponatremia,
  - anemia, and
  - seizures.

Further Reading

1. Kochanek PM, Carney N, Adelson PD, et al. Guidelines for the acute medical management of severe traumatic brain injury in infants, children, and adolescents—second edition. *Pediatr Crit Care Med*. 2012 Jan;13 Suppl1:S1– S82.

Chapter 8

Status Epilepticus

Status Epilepticus

- Impending or early status epilepticus (SE) is defined as protracted or recurrent seizures without complete recovery of consciousness lasting at least 5 minutes.
- Established SE occurs when the protracted or recurrent seizures persist for at least 30 minutes without cessation.
- SE can also be generalized convulsive SE or nonconvulsive SE.
  - Generalized convulsive SE accounts for 73% to 98% of pediatric SE.
  - Nonconvulsive SE is characterized by continuous seizures on electroencephalogram (EEG) without clinical seizures.
- Refractory status epilepticus (RSE) is defined as persistence of seizures despite the appropriate dosing of two antiepileptic agents, typically a benzodiazepine and fosphenytoin, regardless of time elapsed. RSE:
  - accounts for 1.6% to 4% of all pediatric intensive care unit admissions, and
  - develops in 10% to 25% of uncontrolled seizure patients.
- Common etiologies of SE depend on age, but include:
  - Febrile (30%–50%).
  - Remote symptomatic (24%–28%), with known prior neurological injury (eg, stroke, traumatic brain injury).
  - Acute symptomatic (8%–28%), due to acute neurological injury (eg, meningitis, acute traumatic brain injury) or metabolic abnormality (eg, hypoglycemia, hypocalcemia, hyponatremia).
  - Idiopathic (15%).
  - Progressive encephalopathies (1%–5%), including progressive neurodegenerative disease, malignancies, and neurocutaneous syndromes.

- Missed medication dosing or medication tapering are common causes of SE in older children.
- Seizures within the first week of trauma need to be treated acutely; however, there is a low risk of long-term epilepsy.
- Patients who develop seizures after the first week following trauma are more likely to have posttraumatic epilepsy.

Complications

- Overall mortality for pediatric SE is 3% to 7%, but varies depending on type and age; mortality for RSE is 20%–30%.
- Mortality from idiopathic or febrile SE is low (0–2%), but for acute symptomatic SE, mortality is high (12.5%–16%).
- Early in SE, autonomic and metabolic changes include tachycardia, hypertension, hyperglycemia, and increased cerebral blood flow; lactic acidosis may develop from myoclonic contracture and hypermetabolism.
- In late SE, autonomic and metabolic reserves are depleted and hypoglycemia, hypotension, marked hyperthermia, and rhabdomyolysis result; hypoxia, hypercarbia, and cerebral edema may all also develop. Myoglobinuria and hypovolemia may lead to acute kidney injury; hepatic dysfunction and coagulopathy rarely also occur.
- Emergency management can be simplified into a series of sequential interventions (Table 8-1).
- Computed tomography scan of the head is indicated if there is:
  - head trauma,
  - evidence of increased intracranial pressure,
  - focal neurologic deficit, or
  - focal seizure activity.
- Lumbar puncture is contraindicated in the following cases:
  - suspected increased intracranial pressure,
  - focal neurologic deficits,
  - cardiopulmonary instability, and
  - severe coagulopathy or thrombocytopenia.
- If SE persists, consider inducing coma with EEG monitoring. Titrate sedation to seizure suppression, burst suppression pattern, or flat line on EEG.

Table 8-1. Status Epilepticus Emergency Management

Stage	Intervention
Impending SE (seizures persist < 5 min)	Out of the hospital, consider buccal or intranasal midazolam (0.3 mg/kg, max 10 mg) or rectal diazepam (0.2–0.5 mg/kg, max 20 mg) Stabilize the patient • assess airway, breathing, and circulation • apply oxygen • obtain IV or IO access • gather "AMPLE" history: **a**llergies, **m**edications, **p**ast medical history, **l**ast meal, **e**vents preceding Diagnostics: glucose, sodium, calcium, ABG, CBC, PT/PTT, LFTs, anticonvulsant levels, toxicology screen, head CT Administer benzodiazepines: • lorazepam, 0.1 mg/kg IV (max 4 mg) over 1 min, **OR** • diazepam, 0.2 mg/kg IV (max 10 mg) over 1 min Consider pyridoxine 100 mg IV push if < 2 years old
Established SE (seizures persist 5–10 min)	Repeat benzodiazepine and administer either: • fosphenytoin 20 mg/kg IV at 2–3 mg PE/kg/min (max 150 mg PE/min), or • phenytoin 20 mg/kg IV at 1 mg/kg/min (max 50 mg/min) Support airway, breathing, and hemodynamics Continuously monitor vital signs, EKG, and pulse oximetry Consult neurology service
Initial refractory SE (seizures persist > 10 min)	Administer either: • levetiracetam 20–30 mg/kg IV at 5 mg/kg/min (max 3 g), **OR** • valproate 20 mg/kg IV at 5 mg/kg/min

(**Table 8-1** *continues*)

(**Table 8-1** *continued*)

Late refractory SE (seizures persist > 15 min)	Administer phenobarbital 20 mg/kg IV not to exceed 1 mg/kg/min Admit to PICU; anticipate intubation, mechanical ventilation, arterial pressure monitoring, and central venous access for fluids and vasopressors Consider continuous EEG
Coma induction (seizures persist > 25 min)	Initiate coma with midazolam 0.2 mg/kg bolus (max 10 mg) over 2 min, then initiate infusion at 0.1 mg/kg/h Repeat bolus every 5 minutes and titrate infusion up to max 2 mg/kg/h If refractory SE, consider pentobarbital, ketamine, propofol, or isoflurane

ABG: arterial blood gas; CBC: complete blood count; CT: computed tomography; EEG: electroencephalogram; EKG: electrocardiogram; IO: intraosseous; IV: intravenous; LFTs: liver function tests; PE: phenytoin equivalents; PICU: pediatric intensive care unit; PT: prothrombin time; PTT: partial thromboplastin time; SE: status epilepticus

Further Reading

1. Tschudy MM, Arcara KM, eds. *The Harriet Lane Handbook*. 19th ed. New York, NY: Mosby; 2012.
2. Nichols DG, ed. *Rogers' Textbook of Pediatric Intensive Care*. 4th ed. Philadelphia, PA: Lippincott Williams & Wilkins; 2008.
3. Abend NS, Dlugos DJ. Treatment of refractory status epilepticus: literature review and a proposed protocol. *Pediatr Neurol*. 2008;38(6):377–390.
4. Wilkes R, Tasker RC. Intensive care treatment of uncontrolled status epilepticus in children: systematic literature search of midazolam and anesthetic therapies. *Pediatr Crit Care Med*. 2014;15(7):632–639.

Chapter 9

Care of the Newborn

Routine Resuscitation

- When called to the delivery of a newborn, first learn the basic maternal history (time permitting), including the following:
  - the infant's gestational age (term or preterm).
  - if prenatal care was obtained. If possible, gather laboratory information, including ultrasound, estimated fetal weight, etc.
  - complications, if any, leading to delivery (eg, bleeding, change in fetal movements, etc).
  - maternal medications (during pregnancy and in the last 24 hours of pregnancy).
  - maternal health status (eg, medical conditions, immunizations, etc).
- Gather the proper equipment needed for resuscitating a newborn, including:
  - Warm towels. Skin-to-skin contact with the mother can be used to keep the baby warm if the infant is vigorous at delivery. Cover the baby and the mother with a warm towel.
  - A heat source to keep the infant warm. Use radiant warmers if they are available and the infant needs to be separated from the mother for resuscitation.
  - A bulb syringe.
  - A suction device, such as wall suction, that can be used with a suction catheter.
  - An oxygen source.
  - A self-inflating bag or flow-inflating bag that can provide positive-pressure ventilation.
  - A mask, size 0 or 1, that can fit over the mouth and nose of an infant.

- A minute–second timer (though not essential, this helps mark 1 and 5 min and is useful if positive-pressure ventilation is needed).
- Attempt to have a neonatal resuscitation provider available. Larger medical commands should identify people with this experience, even in the deployed environment.

- In the first 60 seconds following birth:
  - Ensure the obstetrical provider securely clamps the umbilical cord before passing the infant to the pediatric team; start the minute–second timer.
  - All infants need to be warm, dry, suctioned, and stimulated; in the delivery room, this takes place within a period of 30 seconds.
    - Dry the infant with the warm towels, discarding damp ones; it is typical to use two or three towels within the first 30 seconds.
    - Rubbing the infant's back and chest while drying is stimulating; if further stimulation is necessary, flicking or slapping the soles of the infant's feet may help.
    - Position the infant's head at the foot of the bed or radiant warmer.
    - Manage the airway and position the infant's head in the sniffing position, allowing for slight hyperextension of the neck (this is usually done by the person closest to the infant's head).
    - Suction the mouth first, and then the nares, with the bulb syringe or suction catheter to clear amniotic fluid that could occlude the airway.
    - Monitor the infant's heart rate by gently palpating the base of the umbilical cord to feel for a pulse, or by listening to the heart with a stethoscope.
    - Heart rate should be above 100 beats per minute (bpm) if the newborn is active and crying.
      - A "vigorous" infant has good muscle tone, has a heart rate greater than 100 bpm, and is crying.
      - If the baby is vigorous, stop resuscitation and allow the infant to transition (transitioning from the intrauterine environment to the outside world takes 2–4 h).

- Skin-to-skin contact with the mother is important at this point, if both the mother and infant are doing well, to keep the infant warm and encourage bonding/feeding.

- All infants are born with a hue ranging from blue to pink; if healthy, newborns will transition to pink with an adequate heart rate and ventilation.
  - Sometimes an infant's hands and feet stay blue even when the rest of the body is pink (acrocyanosis). Assess for central cyanosis by examining the color of the lips, gums, and central trunk; if infant is cyanotic, place a pulse oximeter (if available) on the right hand.
  - A brief period of free-flowing oxygen is beneficial to infants with adequate ventilation and heart rate who remain centrally blue or with a saturation of less than 80% beyond 5 minutes of life. An infant requiring persistent oxygen needs more than typical resuscitation.
- Every infant is assigned an Apgar score (activity, pulse, grimace, appearance, and respiration; Table 9-1) at 1 minute and 5 minutes of life.

Table 9-1. Apgar Evaluation of Newborn Infants

Sign	0	1	2
Heart rate	Absent	Below 100	Over 100
Respiratory effort	Absent	Slow, irregular	Good, crying
Muscle tone	Limp	Some flexion of extremities	Active motion
Response to catheter in nostril*	No response	Grimace	Cough or sneeze
Color	Blue, pale	Body pink, extremities blue	Completely pink

*Tested after oropharynx is clear.

  - The score ranges from 0 to 10, with 10 being given to healthy, vigorous infants.

    - Properly assigning an Apgar score requires training, but knowledge of the components will help providers unfamiliar with scoring know what is important when assessing a newborn during resuscitation and will facilitate communication with a consulting specialist.

Special Circumstances Requiring Advanced Resuscitation

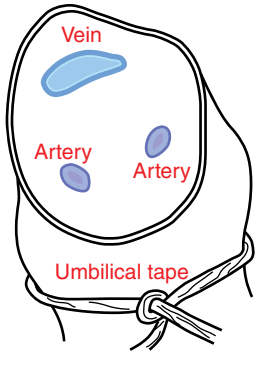
- Advanced resuscitation is required when a term infant is not vigorous after warming, drying, suctioning, and stimulating.
- When an infant is apneic, has a heart rate less than 100 bpm, or has persistent central cyanosis despite free-flowing oxygen, further intervention is required.
    - Ventilation is the most important step in the resuscitation of infants that are not vigorous.
    - The two standard ways of providing ventilation are the self-inflating bag and flow-inflating bag.
    - Various mask sizes are needed, depending on the gestational age of the infant.
        - The mask should cover the infant's mouth and nose and provide a good seal.
        - Most term newborns will use a size 1 infant mask.
        - Preterm infants or infants that are small for their gestational age may need a size 0 newborn mask.
    - Initiate positive-pressure ventilation with 21% fraction of inspired oxygen (FiO_2) in a term infant. If the infant is preterm, start with 40% FiO_2 if a blender is available.
    - Suction the infant's mouth and nose again.
    - Place the mask over the infant's face.
    - Hold the mask with your thumb and index finger; use your other three fingers to lift the jaw into the mask.
    - Ensure there is an airtight seal.
    - Begin delivering breaths at a rate of 40 to 60 breaths per minute; use a manometer if one is available.
    - Pressures should be sufficient to provide adequate chest rise and fall.
        - The first few breaths can require pressures in excess of 25 cm H_2O, but it is rare to need pressures in excess of 40 cm H_2O.
        - Most infants will require pressures of 20 to 25 cm H_2O.

        - Using excessive pressure can cause a pneumothorax.
        - It takes experience to achieve the correct balance of pressure.
            - Novices typically make one of two mistakes: they do not use sufficient pressure to provide adequate chest rise and fall, or they give breaths at a rate exceeding 60 breaths per minute.
            - Using the minute–second timer can alleviate the frequency problem (give a breath every second).
    - If positive-pressure ventilation is adequate, heart rate will improve to over 100 bpm, color will improve, and the infant will start spontaneous respiration; gradually stop giving positive-pressure ventilation.
    - If there is no improvement after 30 seconds, check that the facemask is sealed adequately, reposition the head, and suction out the mouth. At this point, increase the FiO_2 to 100%.
    - If problems persist, reevaluate the pressure being administered; if it is adequate but there is still no improvement, the infant needs to be intubated.
- Intervention is needed when the term infant needs to be intubated.
    - Depending on the location and resources, intubating and ventilating a newborn infant may be impossible.
    - When working in austere environments, it is reasonable and ethical to decide ahead of time the limits of the providers' resuscitative efforts.
    - There are five main differences between the neonatal and adult airway:
        - The infant's head and tongue are proportionally larger than the adult's.
        - The infant's larynx is more anterior and cephalad.
        - The infant's epiglottis is long, narrow, and floppy (making it easier to use a Miller [straight] blade instead of a Macintosh blade).
        - The infant's vocal cords are slanted anteriorly.
        - The cricoid cartilage is the narrowest part of an infant's larynx, not the vocal cords.

- A term infant is generally intubated with a 3.5 or 4.0 uncuffed endotracheal tube (ETT), using a Miller size 1 blade.
- Depth of the ETT should be the approximate weight of in the infant in kilograms plus 6 (term infants can be estimated at 3–3.5 kg).
- Confirm ETT placement by observing one or more of the following:
  - equal chest rise,
  - breath sounds over the lungs and not the stomach,
  - misting inside the ETT,
  - positive color change using a pediatric-size disposable colorimetric carbon dioxide detector (fast, accurate),
  - chest radiograph, and
  - clinical improvement in ventilation and perfusion.
- Upon successful intubation, continue providing positive-pressure ventilation with enough pressure to ensure adequate chest rise at a rate of 40 to 60 breaths per minute.
- In the rare case when an infant does not improve after establishing an airway and providing adequate ventilation, start chest compressions and establish intravenous access to give epinephrine and volume resuscitation, if necessary.

- For emergency vascular access, consider umbilical vein catheter (UVC) placement.
  - Equipment needed for placing a UVC includes:
    - UVC placement kit, if available;
    - 3.5 F or 5.0 F single-lumen umbilical catheter;
    - scalpel (usually in UVC kit);
    - three-way stopcock;
    - normal saline syringes;
    - 5 to 10 mL syringes (usually in UVC kit);
    - Betadine (Purdue Products, LP, Stamford, Conn; usually in UVC kit);
    - umbilical tape (usually in UVC kit);
    - small mosquito forceps; and
    - sterile gloves.
  - Technique
    - Use aseptic technique. Assemble the needed equipment and prepare the line.

- Attach the three-way stopcock to the end of the line. Attach a normal saline syringe to the stopcock and flush the line. The other opening on the stopcock can be used for medication administration.
- Ensure the stopcock is always in the "off to baby" position when it is not being used.
- Lift the umbilical cord by the clamp and clean the cord and surrounding skin with Betadine.
- Tie the umbilical tape around the skin portion base of the cord rather than directly on the cord with a single tie. It should be just tight enough to prevent bleeding but still allow passage of the catheter.
- Use a scalpel to cut across the umbilical cord about 1 to 2 cm above the base of the stump. There will be three vessels, two arteries (tortuous with thicker walls), and a vein (thinner walled and larger).
- If necessary, use small forceps to open the vessel enough to place the catheter (Figure 9-1).



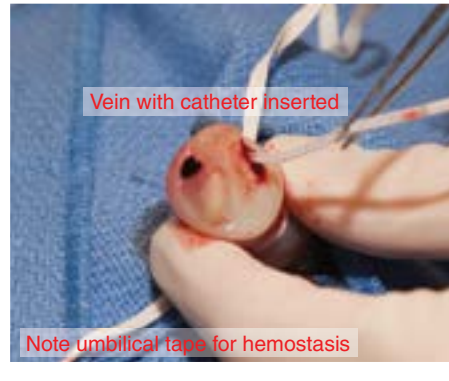


Figure 9-1. The cartoon depicts a typical three-vessel cord; the two smaller umbilical arteries and single larger vein are highlighted. The photo shows the insertion of an umbilical catheter into a previously dilated umbilical vein. Both images demonstrate the application of umbilical tape around the umbilical stump for hemostasis.

- Place the catheter in the vessel and advance to about 3 to 4 cm while drawing back on the syringe. Stop when you get blood return. At this point, you are in the vessel and may administer fluids and medications.
- An emergent UVC is not meant to be a permanent line, so it is usually not sutured in place but rather held by the provider or temporarily taped in place until a more stable line can be placed.
- For more information on emergent UVC placement, see https://www.youtube.com/watch?v=JjBJONanCYU.



Emergency UVC Placement

- If the infant develops a tension pneumothorax, intervention is required.
  - Pneumothorax occurs in a small percentage of all newborns, rarely causing respiratory distress and need for rapid evacuation.
  - There are cases when an infant develops a tension pneumothorax, especially those infants receiving excessive positive-pressure ventilation.
    - The infant will be in respiratory distress (with grunting or nasal flaring or retracting).
    - There are decreased breath sounds on the ipsilateral side.

        - Transilluminating the chest with a light source may show lucency over the side with the tension pneumothorax (chest radiograph confirms the presence of a pneumothorax, but is not usually available before intervention is required). To transilluminate the chest, turn the room lights down and place a light source in the infant's axilla. If pneumothorax is present, light will be seen throughout that side of the chest cavity.
    - Pneumothorax in infants is treated with the same technique used in any age group, except that providers use a smaller-gauge needle and the volume of air evacuated will be less in an infant.
        - Use a needle (23-gauge butterfly works well) attached to a three-way stopcock, with one end closed to air and the other open to a syringe.
        - Insert the needle in the second intercostal space, at the midclavicular line.
            - While inserting the needle, apply gentle retraction to the syringe.
            - When the tip of the needle is in the correct place, you may hear a "whoosh" sound and will be able to rapidly pull back on the syringe.
        - Draw off the air, turning the stopcock off to the patient and on to evacuate the air in the syringe, and repeat until no further air is evacuated from the lungs. Remove the needle and cover with occlusive dressing.
    - Infants with rapidly reaccumulating air require placement of a chest tube, which is beyond the scope of this chapter.
- Intervention is required when the amniotic fluid is meconium stained.
    - Infants who are stressed prior to birth or are late in gestation (more than 41 weeks) are at increased risk to pass stool in the amniotic fluid prior to birth.
    - When the mother's membranes rupture, the amniotic fluid is stained various shades of dark green.
    - This places the infant at risk for aspiration of meconium fluid, which can lead to respiratory compromise (called meconium aspiration syndrome).

- Obstetrical interventions reduce the risk of aspiration and include a transcervical amnioinfusion, bulb suctioning of the nares and mouth on presentation of the head (prior to delivery of the body), and not stimulating the infant at birth.
- The infant should not be stimulated when passed to the neonatal resuscitation team.
  - If the infant is not vigorous, a provider experienced in intubating newborns should place an appropriately sized ETT, attach a meconium aspirator, and suction any meconium from below the vocal cords.
  - This attempt should only last 30 to 60 seconds. If unable to place ETT in this time, abort attempt and proceed with next steps of resuscitation (warming, drying, stimulation, and suctioning the oral pharynx).
  - The vigorous infant requires only routine resuscitation.
- Infants who develop signs of respiratory distress following delivery in meconium-stained fluid may have aspirated meconium.
  - These infants need to be cared for in a facility equipped to care for sick newborns.
  - Consultation with a neonatologist is indicated.

• A preterm infant may require advanced resuscitation.
- An infant born at less than 37 weeks is preterm (the age of viability is 23 gestational weeks; however, this may differ outside the United States depending on local neonatal resuscitation resources).
- Know the available hospital resources in the local area and consult a pediatrician or neonatologist when delivering and resuscitating a preterm infant.
- Remember the basics.
  - For infants born in the third trimester (> 28 wk), basic resuscitation (see Routine Resuscitation, above) may be all that is needed.
  - If positive-pressure ventilation is indicated, a size 0 neonatal mask is typically used.
  - Intubation is achieved using 2.5 to 3.5 ETT to a depth of 7 to 10 cm, depending on the age and size of the infant (Table 9-2).

Table 9-2. Infant Endotracheal Tube Sizes

Tube Size	Depth (cm)	Birth Weight (g)	Gestational Age (wk)
2.5	7	< 1,000	25–29
3.0	7–8	1,000–2,000	30–34
3.5	8–9	2,000–3,000	35–37
3.5–4.0	9–10	> 3,000	> 37

        - Intubation of the preterm infant requires prior experience in the intubation of children and newborns.
    - Following successful resuscitation, infants born at less than 35 weeks or weighing less than 2 kg will typically be admitted to a neonatal intensive care unit. Infants older than 35 weeks may be allowed to stay with their mothers, provided they can be watched closely.
        - Resuscitated infants need to be kept warm and are easily susceptible to cold intolerance.
        - Blood glucose levels should be checked shortly after birth and then every 3 to 5 hours before feeds until feeding is well established, especially in newborns that weigh 10% (or more) below normal predicted weight for their gestational age (Table 9-3). Infants who are too young to begin oral feeds should be started on dextrose 10% in water ($D_{10}W$) at 2.5 to 5 mL/kg/h (60–120 mL/kg/day; consult a pediatric provider to determine exact rates).
        - Vital signs should be checked at least every 4 hours (Table 9-4).
            - Abnormal vital signs, temperature intolerance, hypoglycemia (blood glucose < 40), or poor feeding, regardless of gestational age, should prompt consultation with a neonatologist and transport to a hospital equipped to care for a sick neonate.
            - Consultation with a neonatologist regarding a preterm newborn is always strongly encouraged.
- An infant that does not appear normal may require advanced resuscitation.

Table 9-3. Expected Newborn Weight by Gestational Age

Gestational Age (wk)	Mass (g)
25	650
26	750
27	880
28	1,000
29	1,150
30	1,325
31	1,500
32	1,700
33	1,900
34	2,150
35	2,375
36	2,600
37	2,860
38	3,075
39	3,300
40	3,460
41	3,600
42	3,690

- Few abnormalities require urgent recognition and management in the delivery room (see below). In austere environments, management may be limited to recognition and supportive care without the ability to refer to a neonatal center.

Table 9-4. Normal Infant Vital Signs

Sign	Normal Ranges
Respiratory rate	30–60 breaths/min
Heart rate*	120–160 beats/min
Temperature (axillary)	36.1°C–37°C

*Some healthy, term infants may have a resting heart rate as low as 90 beats per minute while asleep. A heart rate that remains this low in an awake, crying infant is not normal.

- Rarely, an abdominal wall defect may occur and an infant's abdominal contents will develop outside the abdomen. In gastroschisis, the abdominal wall defect is typically to the right side of the umbilical cord. In omphalocele, the defect is through the umbilical cord insertion. In either case, the same steps should be followed.
  - Immediately place the infant in a clear, sterile, plastic bag up to the neck to reduce insensible water losses and minimize exposure of the open bowel; if this is impossible, consider using plastic wrap or warm saturated gauze.
  - Use an oral gastric tube to decompress the intestine (a Replogle tube is preferred); if the infant requires advanced resuscitation, limit positive-pressure ventilation delivered using a bag-valve mask.
  - Place the infant on its side to take pressure off of the bowel.
  - Contact a surgeon.
- Rarely, dusky blue to black bowel requires urgent reduction to prevent ischemia and bowel death. These patients may require initial intense fluid management and attention to acidosis status.
  - Begin $D_{10}W$ at 3.3 to 5 mL/kg/h (80–120 mL/kg/day).
  - Hypotension, poor perfusion, or acidosis should prompt a fluid bolus of 10 mL/kg given over 20 to 30 minutes.
  - Transport infant to a tertiary care facility.
- A neural tube defect, or a protrusion of the spinal cord or the meninges outside the spinal canal, also rarely occurs.
  - Place the infant prone on the infant warmer.
  - Place the infant in a clear, sterile, plastic bag covering the entire defect up to the infant's axilla. In addition, you may cover the protruding mass in warm, sterile gauze soaked in sterile water.
  - Contact a neurosurgeon and arrange for the infant's transport to a tertiary care facility.

        - An upper airway anomaly may rarely occur. Infants are obligate nose breathers. Infants with small jaws, large tongues, and cleft lip or palate may have Pierre-Robin sequence and difficulty keeping their upper airway open. These patients may benefit from being placed in the prone position, and some require placement of an oral airway. Severe cases need bag-mask ventilation and intubation.
            - Infants born with upper airway stenosis, such as choanal atresia, may also need an oral airway to breathe.
            - Typically infants with only cleft lips or palates do not have respiratory issues, but may have difficulty feeding, which can be addressed by a pediatric care provider.
    - Most other cases of infants appearing abnormal can wait for further evaluation until after initial stabilization.
- When a term infant appears ill, advanced resuscitation may be necessary.
    - When an infant appears ill, it is important to ensure that the infant is not septic. Infection in infants can present with soft signs and progress to death within hours. Maternal risk factors for neonatal infection include:
        - intrapartum temperature equal to or exceeding 100.4°F (38°C),
        - amniotic membrane rupture more than 18 hours before delivery,
        - chorioamnionitis, and
        - maternal group B streptococcus status (positive or unknown) and without maternal intrapartum antibiotic prophylaxis.
    - Draw a complete blood count with differential and blood culture.
        - An experienced provider should perform a lumbar puncture to obtain cultures and Gram stain, cell count, and glucose and protein levels.
        - For infants less than 48 hours old, a urine culture is typically not helpful.

- Empiric antibiotic treatment often consists of administering ampicillin and an aminoglycoside (usually gentamicin) or ampicillin and a broad-spectrum, third-generation cephalosporin, such as cefotaxime.
- Ampicillin dose is 100 mg/kg, the interval changes with the degree of prematurity and age in days; use a standard reference, like *The Harriet Lane Handbook*, to confirm dose.
- An ill-appearing infant needs transfer to a tertiary care facility.
  - Consult a pediatric provider.
  - If the term infant is less than 48 hours old, start $D_{10}W$ at 2.5 mL/kg/h (60 mL/kg/day).
  - Infants more than 2 days old require some electrolytes; consult a pediatric provider to determine the appropriate fluids (see recommendations in Chapter 25, Basic Fluid and Electrolytes).
- Observe vital signs.
  - Warm hypothermic infants under a radiant warmer.
  - Check blood glucose.
  - Hypoglycemia can mimic infection; infants who appear ill and are hypoglycemic (blood glucose less than 40 mg/dL) should receive a $D_{10}W$ bolus (2 mL/kg), then be started on intravenous fluids.
- Infants with evidence of respiratory distress or persistent cyanosis require evaluation by a specialist.
  - Obtain an arterial blood gas reading by drawing blood from the radial artery.
  - Place a pulse oximeter on the infant's right hand and left foot to help monitor preductal and postductal saturations.
  - If possible, deliver either positive pressure ventilation via bag mask or intubation, or continuous positive pressure using 100% oxygen.
  - Obtain a chest radiograph and discuss the results with a specialist.
  - Begin a sepsis evaluation (see previous information on evaluating for sepsis).

- If the infant is large or small for gestational age, intervention may be required.

- Infants that are large or small for their gestational age are at risk for hypoglycemia. Check blood glucose once every few hours before feeds (for a total of three times) until the patient is stable.

Routine Care of the Newborn

- Feeding
  - Breast-feeding is the recommended method for feeding a newborn, and may be all that is available.
    - Breast-feeding should occur on demand (ie, when the infant is showing interest in feeding), 8 to 10 times in a 24-hour period, for 10 to 20 minutes on each breast.
    - In the stable, vigorous newborn, initiate breast-feeding immediately after birth; it takes priority over the newborn examination, delivery of vitamin K, and administration of eye drops.
    - Most medications are safe to use during breast-feeding.
      - Exceptions include chemotherapeutic agents, radioactive isotopes, antimetabolites, and drugs of abuse.
      - LactMed (http://toxnet.nlm.nih.gov/newtoxnet/lactmed.htm) is an online website that can be used to determine a medication's safety during breast-feeding; it is available through the National Library of Medicine.
  - Infants fed formula may start with only a half of an ounce per feed, but quickly increase to 2 ounces or more per feed over the next few days.
- Newborn prophylaxis
  - After the first breast-feeding attempt has been accomplished, give 1 mg of vitamin K (phytonadione), if available, intramuscularly in the thigh to prevent hemorrhagic disease.
  - Administer erythromycin (0.5%) ointment or 1% silver nitrate eye drops if available for prevention of gonococcal eye infection.
- General care
  - Infants should be dressed or blanketed in one or two layers more than what everyone else is wearing.

        - Excessive wrapping and layering can lead to hyperthermia.
        - Place wrapped infants in a crib in the supine position.
    - Infants are typically given a sponge bath at birth to remove the vernix.
    - Infants typically void once the first day, twice the second day, then more frequently after that.
        - Most infants will pass stool at least once in the first 24 to 48 hours.
        - The stool will be meconium (dark and tarry) for the first few days.
        - If voiding or passing stool is delayed, consultation is recommended.
    - Most infants stay 2 days in the hospital.
        - A weight loss of up to 10% of the birth weight can be expected, especially in breast-fed infants.
        - Weight loss in excess of 10% should prompt further evaluation and consultation with a specialist.
        - During this time, vital signs should be checked at least every 8 to 12 hours.
        - The newborn should be assessed for jaundice.
            - If possible, all infants should be evaluated for hyperbilirubinemia within the first 24 to 48 hours of life. Infants with yellowing skin should definitely be evaluated for hyperbilirubinemia or an elevated indirect bilirubin.
            - Normal values for a newborn are significantly higher than adult values and vary based on the age (in hours) of the infant. For further information, see the American Academy of Pediatrics article in Further Reading, below . An indirect bilirubin of more than 10 mg/dL after the first week of life in a term infant or persistent elevation of the direct bilirubin fraction require further diagnostic investigation.
- Screening for critical congenital heart disease
    - Pulse oximetry screening can substantially increase the detection of a critical congenital heart defect in infants prior to discharge home (see Kemper, Mahle, Martin, et al in Further Reading).

- Targeted heart defects include: hypoplastic left heart syndrome, pulmonary atresia (with intact septum), Tetralogy of Fallot, total anomalous pulmonary venous return, transposition of the great arteries, tricuspid atresia, and truncus arteriosus.
- All "well" newborns should have pulse oximetry screening between 24 and 48 hours of life.
- A pulse oximeter probe should be placed on the infant's right hand and a foot.
- A screen is positive if:
  - oxygen saturation is less than 90% saturation of oxygen (SpO_2);
  - oxygen saturation is less than 95% SpO_2 in both the right hand and foot on three measures separated by 1 hour; or
  - a greater than 3% SpO_2 difference is noted in oxygen saturation between the right hand and the foot on three measures separated by an hour.
- If a screen is positive, immediately consult a pediatrician, neonatologist, or pediatric cardiologist.
- Depending on location and available resources, further evaluation with echocardiogram is recommended.
- The consulting provider may suggest starting a prostaglandin drip to maintain patency of the ductus arteriosus while transport to definitive care is being arranged.

Further Reading

1. American Academy of Pediatrics Subcommittee on Hyperbilirubinemia. Management of hyperbilirubinemia in the newborn infant 35 or more weeks of gestation. *Pediatrics*. 2004;114:297–316. http://pediatrics.aappublications.org/content/114/1/297.full. Accessed April 30, 2015.

2. Kemper AR, Mahle WT, Martin GR, et al. Strategies for implementing screening for critical congenital heart disease. *Pediatrics*. 2011;128:e1–e8. http://pediatrics.aappublications.org/content/128/5/e1259.full. Accessed April 30, 2015.

Chapter 10

Clinician-Operated Ultrasound

Ultrasound (US) is a rapidly emerging complementary tool for diagnosis and management at the bedside that can help augment medical decision-making. US is ideally suited for austere environments, such as forward deployments and humanitarian assistance missions. In resource-limited settings, US may be the only imaging modality available.

Although no single book chapter can result in clinical US skill proficiency, it can highlight the clinical possibilities. Providers are encouraged to use US-skilled personnel (eg, emergency department physicians, anesthesia providers, radiologists, and personnel certified in peripherally inserted central catheter placement) and the "knobology" primer below to facilitate the clinical applications. Practicing image acquisition on colleagues is also recommended prior to using US on patients.

Supplementary links to additional online US tutorials are found in the chapter references and at the end of each section.

FUNDAMENTALS

Transducer Types

- Linear array (Figure 10-1a): higher frequency probes that generate high-resolution images with a wide area of view at the skin surface.
  - Excellent for procedures such as vascular access, but not as good for assessing deep structures.
  - For infants and small children, the linear array may occasionally be useful for abdominal applications.
- Curvilinear (Figure 10-1b): a lower frequency transducer that penetrates deep tissues with a wide near-field view that makes it well suited for focused abdominal sonography for trauma



Figure 10-1. Transducer types. (**a**) Linear array. (**b**) Curvilinear array. (**c**) Phased array.

(FAST) and abdominal imaging. Limited use for procedures because of lower resolution; the large probe footprint may also limit utility in children.
- Phased array (Figure 10-1c): can visualize more depth of field with a smaller footprint than a curvilinear probe and view deep structures though a small acoustic window. Good for FAST or chest examination, but the narrow near field makes it difficult to identify structures close to the probe or perform procedures.

Depth

- The depth of view is displayed as a measurement scale traditionally aligned on the right side of the screen.
- Depth should be set deeper than the structure being examined so that underlying structures are imaged.

Gain

- Increasing gain increases the sensitivity of the probe, thereby increasing image contrast and brightness.
- If the image is too dark, increase the gain. If it is too bright and fluid-filled structures have shadows, reduce the gain.
- Many machines are equipped with an "Auto Gain" button, which automatically optimizes the gain.

Probe Orientation

- Each probe is equipped with a marker on the side that corresponds with the marker on the screen.
- All images in this text appear in noncardiac convention with the marker pointed to the patient's right side or head.

Scanning Modes

- Most US imaging is performed using two-dimensional B-mode ("brightness" mode; Figure 10-2a).
- M-mode ("motion" mode) examines a small area over time to evaluate movement. This is especially useful for cardiac and pulmonary scanning (see Figure 10-2b).

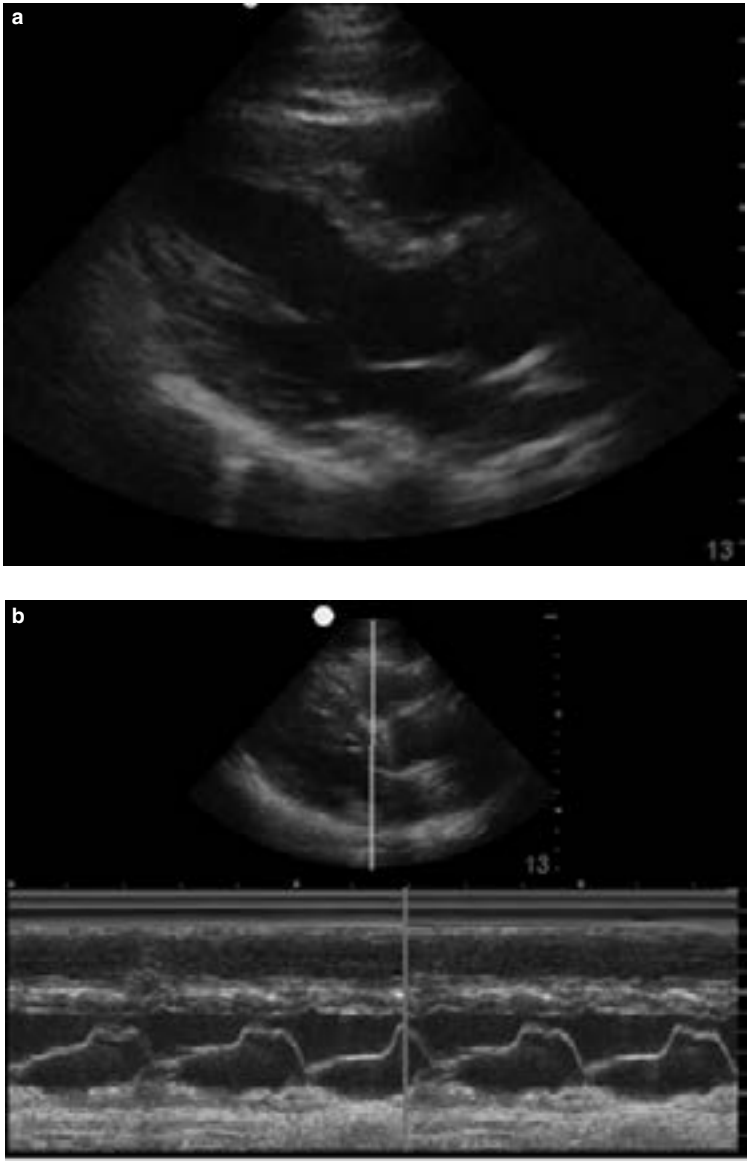


Figure 10-2. Imaging modes. (**a**) B-mode 2-dimensional image of the heart. (**b**) M-mode image with the cursor placed through the mitral valve apparatus.

Online introductory US tutorial:

- Turner L. Bedside Physics, Knobology and Artifacts [Video]. YouTube. http://youtu.be/jLNNdc1LaxI. Published August 17, 2013. Accessed January 2, 2015.



Bedside Ultrasound Physics, Knobology and Artifacts

FOCUSED ASSESSMENT WITH SONOGRAPHY FOR TRAUMA

- FAST (Figure 10-3) is used to detect hemopericardium and hemoperitoneum and has replaced diagnostic peritoneal lavage in trauma patients. It can help guide management.
- The examination is positive when fluid is detected on any of the three abdominal windows or on the cardiac window; the examination is negative when no fluid is detected.
- Sensitivity of FAST in children is much lower than in adults due to smaller structures and a higher frequency of nonbleeding solid organ injury; sensitivity may be increased by performing serial FAST examinations over time.
- A positive FAST examination is meaningful for a bleeding injury; a negative FAST examination should be followed by computed tomography or laparotomy if there is a high index of suspicion for bleeding injury.
- A positive FAST examination alone is not an absolute indication; but in the hypotensive patient, surgery is often indicated.

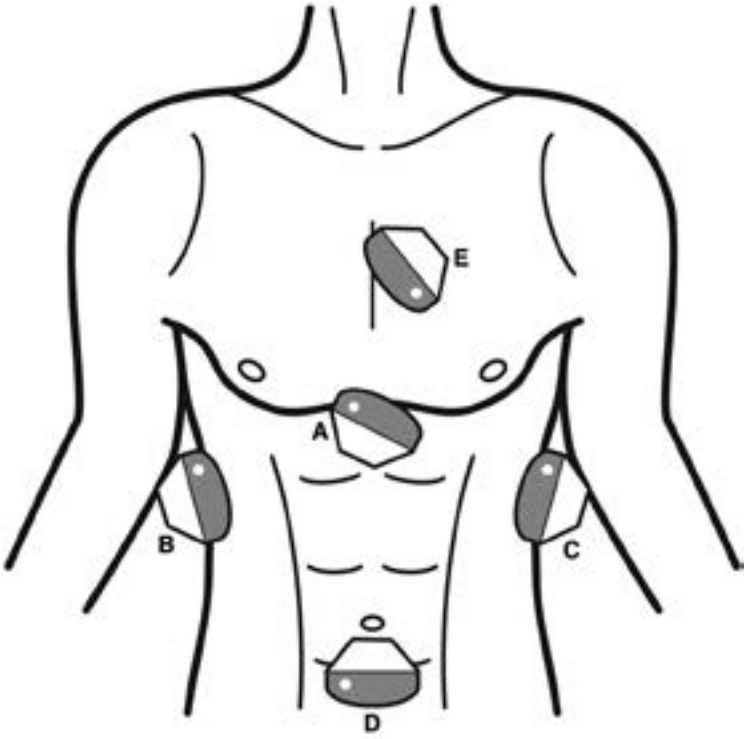


Figure 10-3. Focused assessment with sonography in trauma (FAST) examination windows: (**a**) Subcostal long-axis cardiac, (**b**) Perihepatic/Morison's pouch, (**c**) Splenorenal recess, (**d**) Pelvic, (**e**) Parasternal long-axis cardiac.

Subcostal Long-Axis Cardiac

- Use a curvilinear or phased array probe (Figure 10-4). Do not use a linear probe. Set the machine to the "abdominal" preset.
- Place the patient supine, with the probe below the xiphoid process directed toward the left shoulder and indicator toward the patient's right side; apply downward and forward pressure in a scooping motion.
- Observe a four-chamber view of the inverted heart with the apex to the right of the screen. The liver appears superficial, with the right ventricle located beneath it. A small amount of fluid around the heart can be normal.



Figure 10-4. Subcostal long axis. (**a**) Normal view demonstrating (A) liver, (B) right ventricle, and (C) left ventricle. (**b**) Subcostal view with circumferential pericardial effusion (*).

- Acute blood will appear anechoic (black); a clot may be echoic (bright). Only one bright line surrounding the heart should be seen; effusion will appear as an envelope of fluid and will split this line into two.
- Pericardial tamponade can be demonstrated with diastolic collapse of the right atrium and/or ventricle.

Perihepatic

- The right upper quadrant is the most sensitive location in which to detect free intraperitoneal fluid.
- Align probe parallel to the midaxillary line between ribs 8 and 11 to visualize liver, right kidney, Morison's pouch, subphrenic space, and right pleural space.
- Free fluid appears dark and in the margins surrounding solid structures; it is most commonly noted in Morison's pouch, but it can also be seen in the subphrenic space or at the inferior margin of the liver (Figure 10-5).

Perisplenic (left upper quadrant)

- Align probe parallel to the midaxillary line between ribs 9 and 11; the ideal view contains the left hemidiaphragm, spleen, and left kidney.
- Free intraperitoneal fluid can be seen between the spleen and left kidney, surrounding the spleen, or in the subphrenic space (Figure 10-6); injury is easier to visualize with computed tomography scan than FAST.

Pelvic

- This region is best observed in the longitudinal and transverse views (Figure 10-7) when the bladder is full—before inserting a Foley catheter—with the probe above the pubic symphysis and the probe indicator toward the patient's head.
- In females, fluid will be present in the pouch of Douglas posterior to the uterus; in males, fluid appears in the rectovesicular pouch dorsal to the bladder.

Parasternal Long-Axis Cardiac

- Provides the optimal cardiac view and allows for estimation of cardiac function (Figure 10-8).

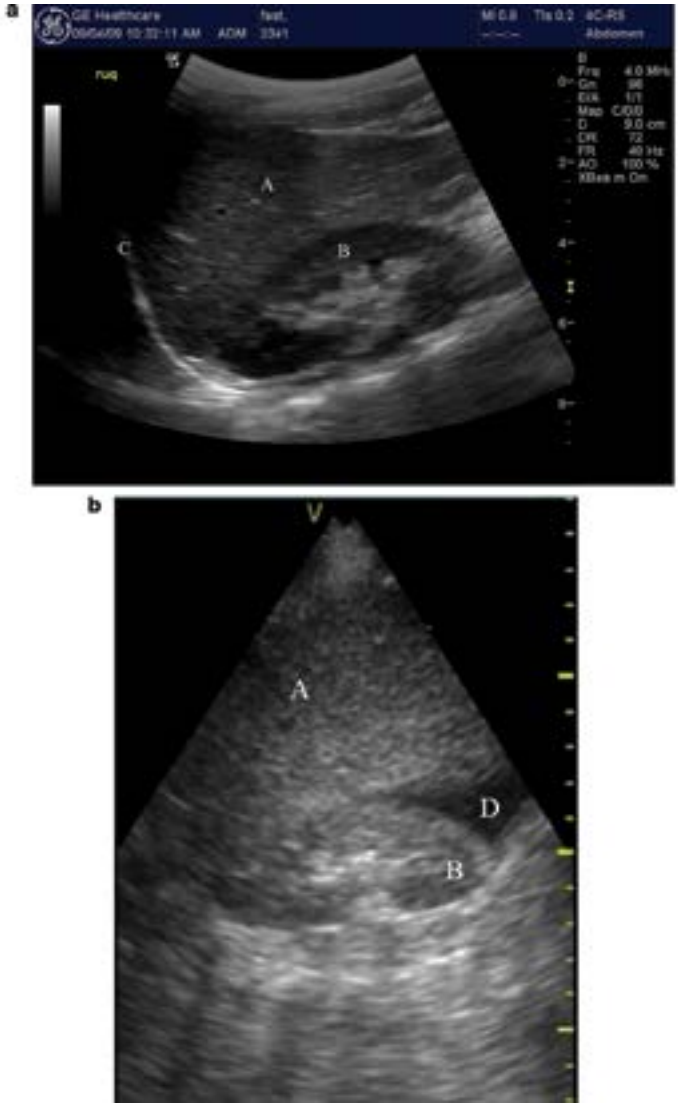


Figure 10-5. Right upper quadrant focused assessment with sonography in trauma (FAST). (**a**) Normal FAST examination in the perihepatic region demonstrating (A) liver, (B) kidney, (C) diaphragm. (**b**) Positive FAST finding indicated by (D) free fluid.

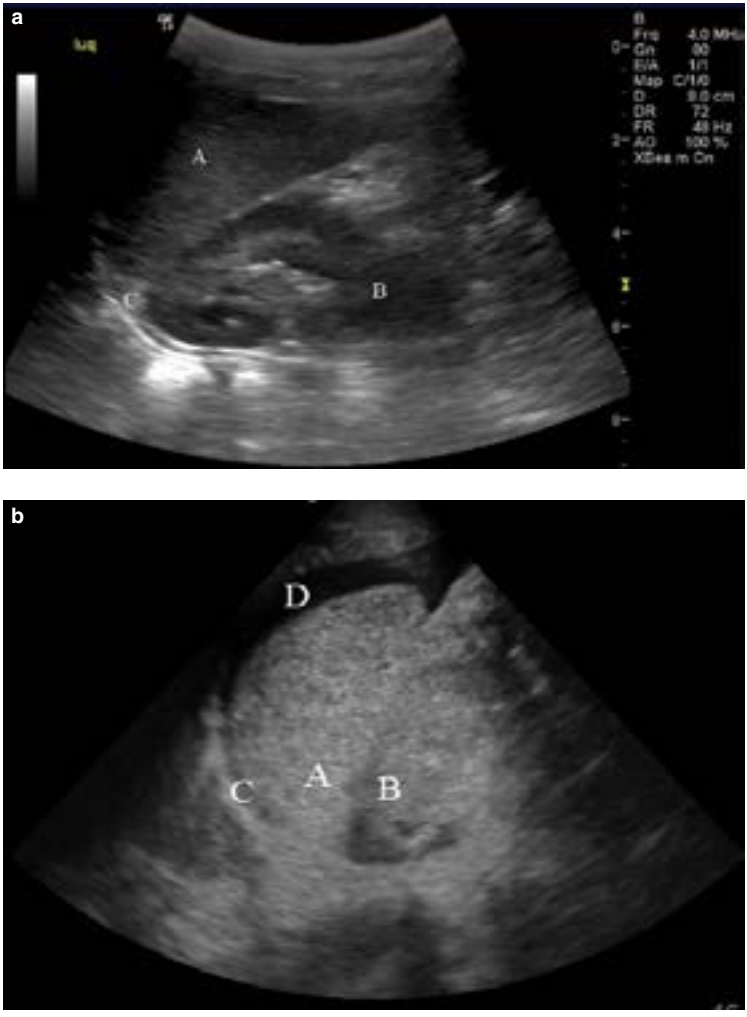


Figure 10-6. Left upper quadrant focused assessment with sonography in trauma (FAST). (**a**) Normal FAST findings in the perisplenic region demonstrating (A) spleen, (B) kidney, (C) diaphragm. (**b**) Positive FAST finding indicated by (D) free fluid.

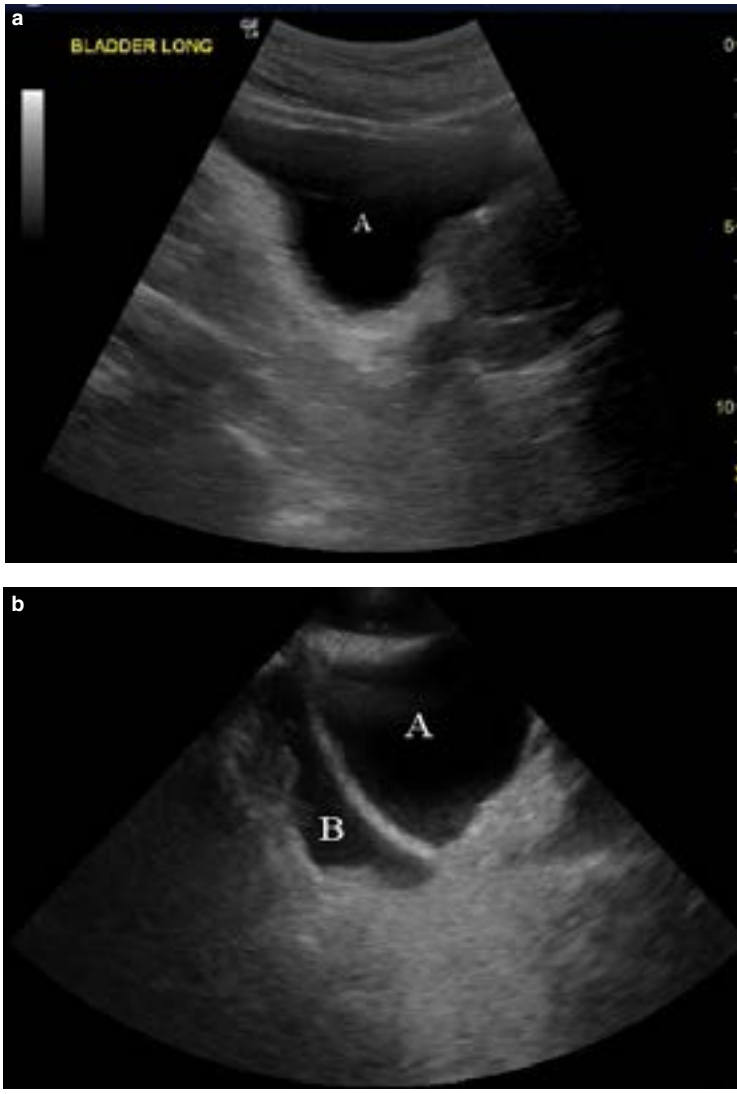


Figure 10-7. Pelvic focused assessment with sonography in trauma (FAST). (**a**) Normal pelvic FAST, longitudinal view, demonstrating (A) bladder. (**b**) Positive FAST finding in the pelvic region, indicated by (B) free fluid.

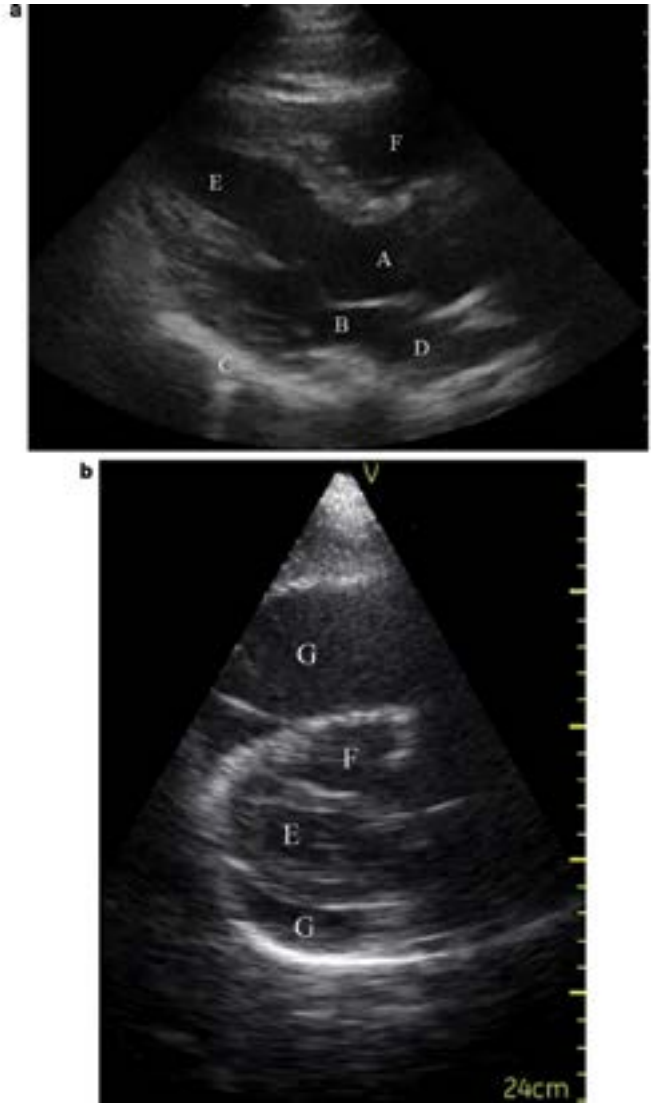


Figure 10-8. Parasternal long-axis view. (**a**) Normal heart demonstrating (A) left ventricular outflow tract, (B) mitral valve apparatus, (C) pericardium, (D) left atrium, (E) left ventricle, and (F) right ventricle. (**b**) Large pericardial effusion in parasternal long-axis view, (G) pericardial effusion.

- Use the phased array probe. Position probe at left sternal edge between 2nd and 4th intercostal space, with the probe marker pointing to patient's left hip if in the abdominal preset.
- Tilt the probe so the view shows the left ventricular (LV) cavity as widely as possible while still showing the left atrium, the mitral valve apparatus, and the LV outflow tract with the aortic valve leaflets moving.
- Assess cardiac contractility by measuring or estimating the fractional shortening (FS) of the LV in M-mode across its diameter at the level of the open mitral valve leaflets, perpendicular to the main axis of the LV; normal FS ranges between 28% and 44%. It is easy to be positioned off-axis and accidentally measure a higher FS than normal; therefore take time to adjust the probe position so the diameter of the chamber is as large as possible before assessing FS of the chamber at the level of the tips of the mitral valve.
- The equation for FS is:

$$FS = \frac{LVd\text{-}LVs}{LVd} \times 100$$

- If the anterior leaflet of the mitral valve (closest to the interventricular septum) comes within a few millimeters of the septum as the LV fills in diastole, this typically indicates LV function is not diminished.
- A low FS estimate associated with little change in LV diameter suggests reduced cardiac function.
- If the patient is tachycardic with a large FS and significant obliteration of the LV cavity, this suggests hypovolemia.
- Correlate with inferior vena cava observation (below).
- Online FAST tutorials:
  - Hoffmann B. *Ultrasound Guide for Emergency Physicians*. American College of Emergency Physicians. http://www.sonoguide.com/FAST.html. Published 2008. Accessed January 2, 2015.
  - Zwanck M. eFAST: extended Focused Assessment with Sonography in Trauma [Video]. YouTube. http://youtu.be/Yg78aU93SZE. Published September 5, 2013. Accessed January 2, 2015.

- Online echocardiography tutorial:
  - Turner L. FATE: Focused Assessed Transthoracic Echo [Video]. YouTube. http://youtu.be/dsg1CgPdL30. Published March 3, 2013. Accessed January 2, 2015.



eFAST : extended Focused Assessment with Sonography in Trauma



Focused Assessed Transthoracic Echo, FATE exam

PLEURAL EFFUSION AND HEMOTHORAX

- The right upper quadrant and left upper quadrant views obtained for the FAST examination also provide information about the presence or absence of fluid in the thorax, such as pleural effusion or hemothorax.
- Normal hemidiaphragm appears as a bright (hyperechoic) line just above the liver and spleen.
- Normal lung appears as a bright echogenic surface beyond the diaphragm and is often a normal "mirror image" of liver or spleen.
- If a hemothorax or pleural effusion is present, the effusion will appear anechoic above the hemidiaphragm (Figure 10-9).

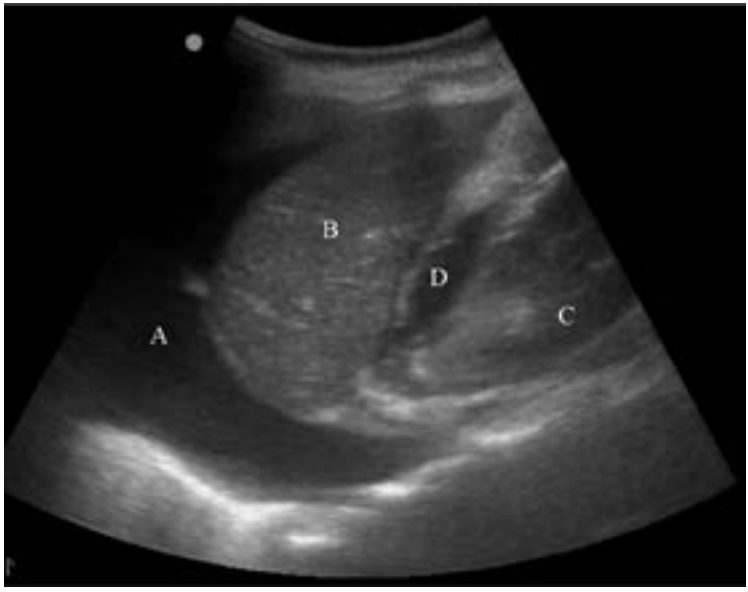


Figure 10-9. Large left-sided pleural effusion. (A) Effusion, (B) spleen, (C) kidney, note also (D) ascites.

- Thoracic fluid can also be visualized directly through the chest wall using the linear or curvilinear array by positioning the probe in the intercostal spaces with the marker directed toward the head and the patient in an upright or semi-upright position.
- Acoustic windows are easier to obtain in neonates/infants due to incomplete ossification of bone.
- Each lung should be assessed systematically in both transverse and longitudinal views, scanning from the apex to the hemidiaphragm in the midclavicular line, midaxillary line, and posteriorly medial to the scapula.



Figure 10-10. B-lines in lung US (white arrows); pleural line (gray arrow).

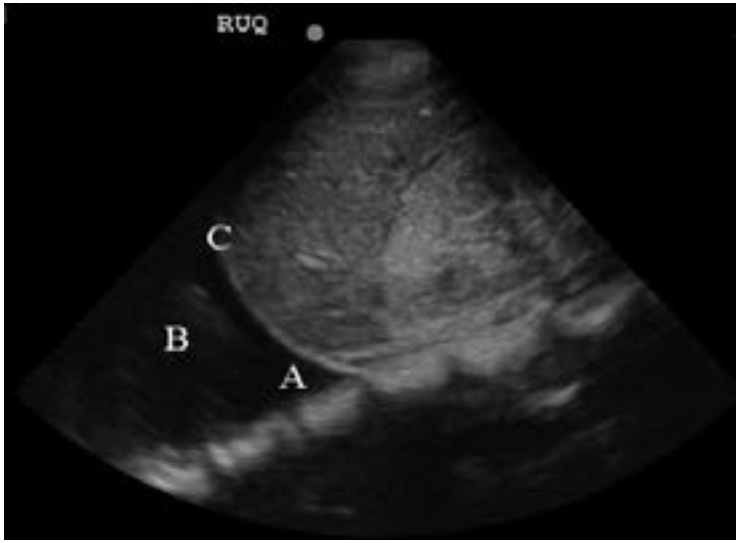


Figure 10-11. Pleural effusion. (A) Effusion, (B) lung, (C) diaphragm.

- The interface of the pleura with the lung produces a strong reflective surface with comet-tail artifacts called B-lines (Figure 10-10).
- Movement of the visceral pleura against the parietal pleura will create the appearance of lung sliding; absence of this sign can be indicative of separation of the pleural interface from effusion or pneumothorax.
  - US is very sensitive for the detection of pleural fluid, able to detect as little at 3 to 5 mL in pleural space.
  - In a simple pleural effusion, anechoic (dark) nonloculated pleural fluid will change in shape and position with the patient's breathing or movement (Figure 10-11).
  - In a complicated pleural effusion, findings may vary, but fluid will likely be echogenic or anechoic, with mobile echogenic debris and septations within the effusion.

THORACENTESIS/TUBE THORACOSTOMY PLACEMENT

- Once an effusion has been identified, US is useful in selecting a site for thoracentesis.
- With the patient in a flat or slightly recumbent position, scan for an appropriate pocket for insertion; for thoracentesis, consider a sitting position leaning forward onto a table.
- A large, dark, anechoic area away from adjacent lung structures and the hemidiaphragm is the ideal insertion site.
- Once the ideal location is chosen, either mark the spot and proceed with thoracentesis or chest tube placement in the usual blind manner, or refer to the below vascular access discussion for details about dynamic needle guidance.
- Online chest tube insertion tutorial:
  - Elbeery, J. Ultrasound Guided Chest Tube Insertion for Pleural Effusion [Video]. YouTube. http://youtu.be/xVEfyXOC-mg. Published January 15, 2014. Accessed October 8, 2014.



Ultrasound Guided Chest Tube Insertion for Pleural Effusion

PNEUMOTHORAX

- Pneumothorax is characterized by obliteration of normal US lung artifact, as air does not transmit US.

- To identify pneumothorax, look for an absence of signs seen with normal lung: (1) no lung sliding at the normal pleural line, (2) absent B-lines, and (3) no concurrent effusion.
- Finding a "lung point" is highly suggestive of a pneumothorax. This is an area where you see a normal lung (lung sliding, B-lines, etc) moving in and out of an area without lung sliding or B-lines.
- US for significant pneumothorax has a high negative predictive value. Pleural movement suggests pneumothorax is unlikely. Factors such as pleural adhesions and poor windows may decrease the sensitivity of absent lung sliding for pneumothorax.
- If there are questionable findings on B-mode US, the lungs can also be examined using M-mode (Figure 10-12).
  - Normal pleural sliding will appear as a grainy "seashore" sign below the pleural line.
  - Pneumothorax has no movement beneath the pleural line, known as the "barcode" or "stratosphere" sign.
- Online pneumothorax tutorial:
  - Cook J. Critical points: beside ultrasound for pneumothorax [Video]. YouTube. http://youtu.be/ebCbewLBNGM. Published February 20, 2011. Accessed January 2, 2015.



Critical Points: Bedside Ultrasound for Pneumothorax

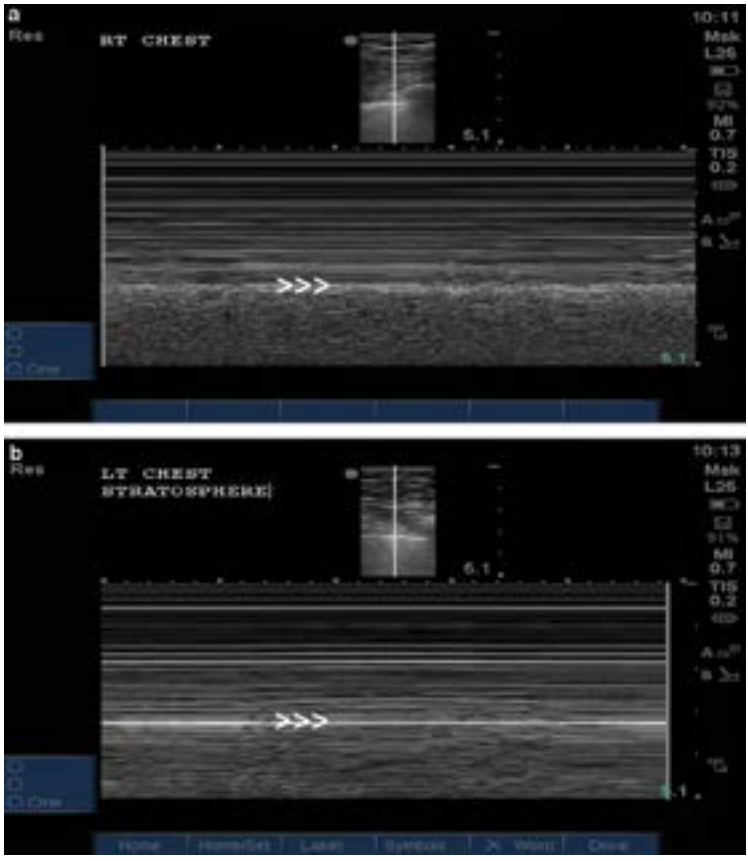


Figure 10-12. M-mode tracings of the lung. In both images, the transducer is sagittally oriented and the cursor placed between rib spaces through the pleural line. With normal lung (a), normal sliding movement between the visceral and parietal pleura leads to a grainy appearance deep to the pleural line, described as the "sand on a seashore" sign. With pneumothorax (b), there is no respiratory variation or pleural sliding; the straight lines deep to the parietal pleura are described as a "barcode" or "stratosphere cloud" sign.

VOLUME STATUS

- The diameter of the inferior vena cava (IVC) is suggestive of intravascular volume status in many conditions.

- Place a curvilinear or phased array probe below the xiphoid process, with the indicator oriented toward the patient's head, and tilt the tail of the probe toward the patient's left so the IVC is seen sagittally where it lays to the right and anterior of the patient's spine. The IVC enters the heart as it crosses the diaphragm, differentiating it from the aorta.
- Respiratory variation in IVC diameter suggests lower intravascular volume when a patient's symptoms are consistent with shock (Figure 10-13).
- Finding a full IVC with no respiratory variation may be more meaningful in pediatric shock management, as it suggests robust right heart filling pressures.
- Positive pressure ventilation, cardiac tamponade, tension pneumothorax, right heart failure, arrhythmia, and increased intraabdominal pressure can interfere with measurement.

VASCULAR ACCESS

- US using a linear transducer provides real-time visualization to help with placement of both peripheral IV and central venous catheter (CVC) lines, allowing greater first-pass success, faster time to insertion, and fewer complications.
- Short-axis approach: the probe is oriented perpendicular to the axis of the vessel such that the vein will appear circular (Figure 10-14a); often the preferred view for initial insertion.
- Long-axis approach: the probe is oriented parallel to the axis of the vessel so the vein will appear as an anechoic dark horizontal stripe across the screen (Figure 10-14b); can be used to check if the wire or catheter is in the vessel.
- In addition to standard CVC supplies, a sterile plastic probe cover and sterile gel are necessary.
- Short-axis technique for CVC insertion:
  - Choose an insertion site and use US to delineate anatomy. Femoral and internal jugular are the easiest sites for US guidance; subclavian is much more difficult.
  - Distinguish the vein from the artery. Veins will appear anechoic (dark), be compressible, have thinner walls, and be less pulsatile. Arteries will appear more pulsatile, have thicker walls, and will not be as easily compressible.

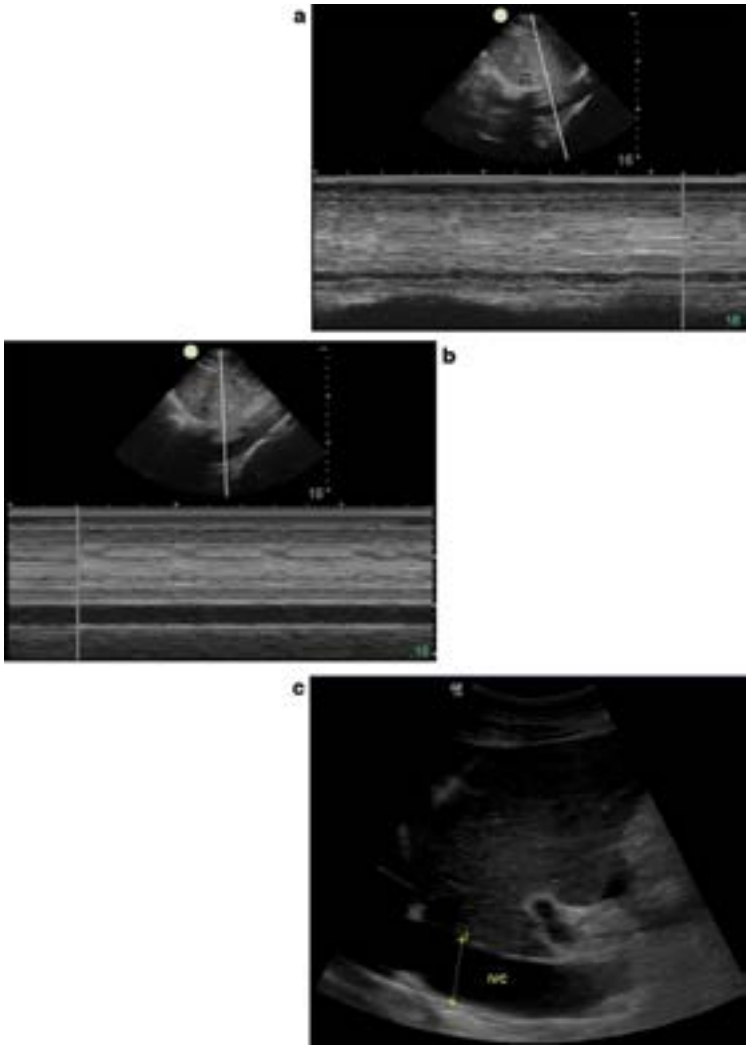


Figure 10-13. (**a**) M-mode view of the IVC with respiratory variation. The cursor is placed below the diaphragm and confluence of the hepatic veins. IVC variation in the vessel diameter through the respiratory cycle. (**b**) A full IVC that does not vary over time is seen. (**c**) The IVC can also be measured in B-mode, comparing maximum and minimum diameters on separate images in a video loop.

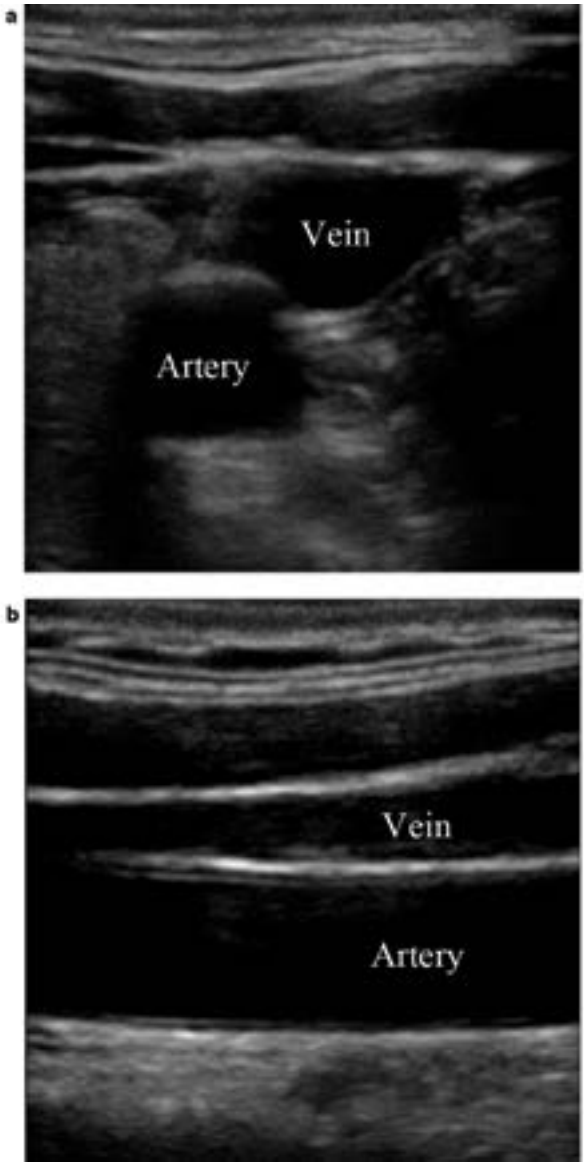


Figure 10-14. (**a**) Short-axis view and (**b**) long-axis view of the internal jugular vein.

- Prepare and drape insertion site; open the sterile probe cover and place US gel inside the plastic sleeve. Have an assistant help place the transducer into the sterile sleeve.
- Place sterile US gel over the insertion site.
- Start in the short-axis view (Figure 10-14a), holding the probe perpendicular to the skin.
- Maneuver the probe so the target vein is in the center of the screen.
- Enter the skin within 1 to 2 mm from the transducer such that the finder needle enters directly under the transducer.
- Identify the needle tip on the screen, then move the transducer forward about 2 to 3 mm ahead of the needle tip. Advance the needle until the tip is just visible.
- Continue this "leap-frog" approach until the tip of the needle has entered the target vessel. As the needle pushes against the vein wall, you should see the wall indent.
- Small forward and backward movements ("bouncing") of the needle as it advances may help identify the tip.
- Once in the target vessel, rotate the transducer into the long-axis plane to verify needle position prior to advancing the guidewire.

- Long-axis technique (Figure 10-14b): Position the transducer overlying and centered on the vessel onscreen.
  - Advance the needle in the plane of the US beam until it enters the wall of vessel, at which point either blind or US-guided wire insertion is performed.
  - After threading the guidewire but before dilating, confirm that the wire is inside the lumen of the vein using both the short-axis and long-axis views (Figure 10-15).
- After you have confirmed the wire is in the correct location, complete the rest of the CVC procedure.
- Online US assisted central venous access tutorial:
  - Ortega R, Song M, Hansen CJ, Barash P. Ultrasound-guided internal jugular vein cannulation. *N Engl J Med*. 2010;362:e57-e57. http://www.nejm.org/doi/full/10.1056/NEJMvcm0810156. Accessed January 2, 2015.



Figure 10-15. Long-axis needle approach in right internal jugular vein, arrow points to needle shadow within the vessel.

PERIPHERAL INTRAVENOUS CATHETER INSERTION

- Linear US probes set to a very shallow depth can help identify suitable peripheral veins.
- The basilic vein in the proximal arm and the saphenous vein in the leg are good locations for peripheral venous access.
- Steps are similar to US-guided CVC access without the need for sterile preparation and use of a wire.
- Scan peripheral veins proximally and distally from the insertion site for 2 to 3 cm to ensure that the vein is relatively straight and has no valves. Ideally the vessel will be less than 1 cm deep from the skin surface, and at least 2 to 3 mm in diameter.
- The probe should be placed with minimal pressure on the site because veins are easily collapsible.
- When inserting the IV, use a shallow entry angle (< 20 degrees); sharper angles may kink the catheter.

- After insertion, US can confirm that enough catheter (1–1.5 cm) is in the lumen to prevent extravasation.
- Online US assisted peripheral IV insertion tutorial:
  - Joing S, Strote S, Caroon L, Wall C, Hess J, et al. Videos in clinical medicine. Ultrasound-guided peripheral IV placement. *N Engl J Med*. 2012 Jun 21;366(25):e38. http://www.nejm.org/doi/full/10.1056/NEJMvcm1005951. Accessed January 2, 2015.

OTHER APPLICATIONS

- US can help identify lung consolidation consistent with pneumonia. Consolidation causes a loss of B-lines, and the lung may appear similar to liver, or an irregular geographic pattern of bright and dark areas.
- A wide variety of musculoskeletal applications are useful, such as identification of bony fracture, tendon injuries, foreign bodies, and differentiation of abscess from cellulitis.
- Other common abdominal applications include evaluation for appendicitis, intussusception, bowel obstruction, hypertrophic pyloric stenosis, cholecystitis, hydronephrosis, and urinary bladder volume prior to catheterization.
- US can assist in procedural guidance for vascular access, thoracentesis, paracentesis, pericardiocentesis, nerve blocks, arthrocentesis, and lumbar puncture.
- The reader is referred to the host of medical literature, US textbooks, and online resources for more information about these (and other) additional applications.

FURTHER READING

1. Leeson K, Leeson B. Pediatric ultrasound: applications in the emergency department. *Emerg Med Clin N Am* 2013;31:809–829.
2. Levy JA, Noble VE. Bedside ultrasound in pediatric emergency medicine. *Pediatrics*. 2008;121:e1404–1412.
3. Nicolaou S, Talsky A, Khashoggi K, et al. Ultrasound-guided interventional radiology in critical care. *Crit Care Med*. 2007;35:S186–S197.

4. Rozycki GS, Feliciano DV, Davis TP. Ultrasound as used in thoracoabdominal trauma. *Surg Clin North Am*. 1998;78:295–310.

5. Schindler E, Schears GJ, Hall SR, et al. Ultrasound for vascular access in pediatric patients. *Paediatr Anaesth* 2012;22:1002–1007.

6. Supakul N, Karmazyn B. Ultrasound of the pediatric chest—the ins and outs. *Semin Ultrasound CT MR* 2013;4:274–285.

Additional Online Ultrasound References

1. Beraud AS. *Echocardiography in the ICU*. Stanford University. 2012. https://web.stanford.edu/group/ccm_echocardio. Accessed January 2, 2015.

2. Hoffmann B. *Ultrasound Guide for Emergency Physicians*. American College of Emergency Physicians. 2008. http://www.sonoguide.com. Accessed January 2, 2015.

Chapter 11

Aeromedical Evacuation

Aeromedical evacuation (AE) is the armed forces' system of evacuating patients via aircraft, usually from hostile or austere environments, to safer or more medically capable facilities. AE systems differ based on several variables, such as aircraft type (ie, rotary wing, tilt-rotor, or fixed wing), whether a location has dedicated evacuation aircraft or uses a vehicle of opportunity, the simplicity of arranging movement, the scale of distances involved, and en route capabilities.

The US Army uses dedicated rotary-wing aircraft to support the AE mission and provides medical AE for all categories of patients, as well as support to other services. In the Army, these assets are located in the medical company (air ambulance), which falls under the general support aviation battalion, combat aviation brigade. In addition, triservice aircraft (eg, C-130 Hercules, C-17 Globemaster fixed-wing platforms, V-22 Osprey, UH-60 Blackhawk, and CH-47 Chinook rotary-wing aircraft) may also be configured for patient transport.

The evacuation and en route medical care of combat wounded is the most recognized mission of all medical evacuation assets. However, the vital functions of medical evacuation resources encompass many additional missions and tasks that support the military health system, including transferring patients between medical treatment facilities (MTFs) within the joint operations area and from MTFs to US Air Force aeromedical staging facilities, as well as emergency movement of class VIII medical supplies, blood and blood products, and medical personnel and equipment.

Transport Structure

United States Transportation Command (TRANSCOM) and the Air Force's Air Mobility Command operate a sophisticated worldwide AE system capable of safely transporting patients of all ages and at all levels of care across intercontinental distances between MTFs. Crews are composed of flight nurses and technicians, augmented by critical care air transport teams (CCATTs) when medically indicated. These expert teams are composed of a critical care qualified physician, intensive care unit nurse, and respiratory therapist. They have the expertise and equipment to provide in-flight intensive medical care.

Because pediatric patients are more vulnerable than adults to the hazards of flight, evacuating children and neonates by air presents unique challenges. Urgent treatment focused on life-threatening or organ-threatening problems must precede a definitive diagnosis. The impact of flight physiology and the need for specialized transport teams should be factored into mission planning.

Hazards of Flight

Hypoxia

- Routine cruising altitude for fixed-wing AE flights is 30,000 to 40,000 feet above mean sea level. The cabin altitude routinely varies between 6,000 and 10,000 feet (average 8,000 feet) above mean sea level, maintained by pressurization of the aircraft.
- In a child without cardiopulmonary disease, this results in a corresponding decrease in the oxygen saturation from near 100% at sea level to 90% at altitude.
- Administering 2 L/min oxygen by nasal cannula increases the oxygen saturation to approximately 100%.
  - In patients with cardiopulmonary disease, anemia, or increased metabolic demands due to burns, sepsis, or recent operative procedures, a higher flow rate may be required to maintain tissue oxygenation.
  - Pulse oximetry is required when administering supplemental oxygen.

Decreased Cabin Air Pressure

- With the climb from sea level to cruising cabin altitude, the volume of a trapped gas increases as the ambient barometric pressure decreases, causing trapped gases within body cavities (pleura, skull, viscera, etc) to expand (Boyle's Law). At a cabin altitude of 8,000 feet, volume increase approaches 40% compared to mean sea level.
- Nasogastric tubes, gastrostomy tubes, and ostomy bags must be vented.
- The pressure of ballooned devices (eg, endotracheal tube cuffs, Foley catheters) should be adjusted during the climb and descent phases of flight.
- Strongly consider leaving drains (including chest tubes) in place for flight. Patients who have had chest tubes removed generally must wait 24 hours before flying and must be cleared radiographically to confirm pneumothorax resolution.
- When gas in cavities is not readily accessible to decompress (eg, pneumocephalus) and urgent AE is required, a cabin altitude restriction (CAR) can be requested (see CAR, below).

Thermal Stress/Humidity

- Temperature fluctuations can adversely affect infants because of their high surface-area-to-body-mass ratio and immature thermoregulatory systems.
- The Joint Theater Trauma System maintains a Clinical Practice Guideline on Hypothermia Prevention (http://usaisr.amedd.army.mil/cpgs.html) that should be reviewed prior to transporting patients. It discusses specific blankets and requirements for temperature monitoring and regulation.
- Prior to and during transport from the point of injury, patients should be wrapped in multiple layers (wool and space blankets) to conserve heat.
- Temperature should be monitored and documented prior to and during evacuation. Although not as accurate as a core body temperature measure, skin temperature devices (eg, Tempa-Dots [3M Co, St. Paul, Minnesota]) provide an easy way to regularly monitor and document the patient's temperature in flight.

- Decreased cabin humidity (~ 1%) promotes dehydration.
  - An incubator or other flight-approved isolette can provide a neutral thermal and humid environment for infants.
  - At cruise altitude, increased fluid flux occurs into the extravascular space, and increased insensible fluid losses exacerbate dehydration.
  - Standard maintenance fluid calculations must be adjusted.

Environmental Factors

- Vibration, acceleration and maneuvering forces, subdued lighting (due to combat conditions), noise (auscultation is almost impossible), multiple patient handoffs, and limited space, equipment, and supplies all impose additional risk.
- This is a difficult environment in which to evaluate or manage pediatric patients; the above factors promote equipment disconnections or malfunctions and cause patient disorientation and fatigue.
- These factors are especially significant in tactical evacuation missions using rotary-wing aircraft, where space limitation severely impedes the ability of a medical crew to monitor and perform intervention maneuvers in flight; fortunately, these flights are usually of shorter duration.
  - All lines and tubes must be carefully secured prior to transfer to the aircraft and frequently checked en route to prevent dislodgment during the requisite multiple patient movements.
  - Orthopedic casts must be bivalved for swelling if placed less than 72 hours before flight.
  - Consider fasciotomy in patients at high risk of developing a compartment syndrome.
  - Intubate patients at risk for airway compromise or with borderline respiratory status; establishing an emergent airway may be difficult or even impossible in a child while in flight.
- Prolonged mission duration
  - Strategic AE between major command areas of responsibility can exceed 10 hours and entail unanticipated delays due to operational considerations, equipment failure, weather, and other factors.

- Ensure patients have sufficient medication, blood products (if indicated), and pediatric age-appropriate equipment available; this is especially important with infant and toddler transports because most AE supplies are sized for adults.

- CAR
  - Rotary-wing and tilt-rotor aircraft cannot restrict the cabin altitude.
  - Patients with severe pulmonary disease and marginal oxygenation who cannot be further optimized by increasing fraction of inspired oxygen, positive end-expiratory pressure, circulating hemoglobin, or inotropes/pressors require a CAR to maintain the cabin air pressure near that of the origination altitude and thus increase the cabin atmosphere's partial pressure of oxygen to normal.
  - A CAR forces the aircraft to fly lower, slower (prolonging the mission), less efficiently (possibly adding a fuel stop), and through more turbulent air.
  - A CAR may place the aircraft at risk in the combat environment.
  - Other conditions warranting a CAR include penetrating eye injuries with intraocular air and trapped air that cannot be evacuated before flight (eg, pneumoencephalus), or a small bowel obstruction.
- Noncertified equipment
  - Approved AE equipment has been extensively tested to ensure that it is safe for the aircraft to operate in flight (the equipment will not interfere with the aircraft) and safe for the patient (aircraft systems will not alter equipment function).
  - A waiver must be granted for noncertified or nonstandard medical equipment.
  - Local AE support staff can identify what equipment is not certified.

Special Considerations

- AEs of intubated, pressor-supported, or otherwise unstable neonatal and pediatric intensive care patients demand special care and planning. Every effort should be made to create a transport team with the prerequisite pediatric skills.

  - Adding a physician or nurse anesthetist skilled in pediatric intubation, a respiratory therapist, or a pediatric-skilled registered nurse to the transport team may have a huge impact on patient safety.
  - Physiological deterioration is common during pediatric critical care transport and should be anticipated; unrecognized asphyxia is the primary cause of deterioration.
  - The transport team must be prepared for emergencies such as airway-related events, hypotension, loss of crucial intravenous access, and cardiopulmonary arrest.
  - Although pediatric and neonatal CCATTs exist, they are unlikely to be quickly available in hostile environments.
- Neonatal teams typically transport patients from birth to 3 months of age; pediatric teams generally transport critically ill patients ages 3 months to 14 years of age.
- Requests are coordinated between the originating physician, the validating flight surgeon at the patient movement requirements center (PMRC), and the destination/accepting physician.
- Close coordination between the sending facility and the PMRC is necessary to consider factors as such as the patient's weight, transport isolette size, in-flight care requirements, acuity, and team composition.

Humanitarian Transport Requests

- The process of arranging pediatric humanitarian evacuations out of theater can take between 6 and 12 months.
- Appropriate patient selection is critical; the ideal patient will have only a single, fixable, stable problem.
- The lack of suitable host-nation care must be confirmed and documented; regional care is preferred over transport to the continental United States.
- Individual cases for humanitarian evacuation out of theater are unlikely to be successful without a passionate advocate; personalizing the case with photos and compelling narrative is crucial for success.
- These complex requests often require coordination with the local US embassy or State Department, host-nation medical officials, and transit nations' ministries of foreign affairs (or equivalent).

- Identify partners within the country of origin and within international nongovernmental organizations (eg, using resources within the US consulate and Shriners International for a child who needs reconstructive plastic surgery long after a disfiguring burn).
- For Southwest Asia, military approvals are required from local command through Central Command.
- All evacuated children must have an attendant; those needing military transport require "Secretary of Defense Designee" status.
- Coordination also includes travel to a receiving medical center once in the continental United States, obtaining diplomatic transit clearance during wait for ongoing flights, and return transport.
- Contact the servicing PMRC for guidance.

Key Steps for an Aeromedical Evacuation Request

- Contact the local flight surgeon or AE liaison to assist with an en route care plan and timing/precedence of evacuation; a patient movement request is generated by the sending MTF.
- Include equipment and support requirements, nonmedical attendants (parent, guardian), movement precedence, litter or ambulatory (or both), and services required at the accepting facility, including an accepting physician with a contact number.
- The servicing PMRC receives the patient movement request through the TRANSCOM Regulating and Command and Control Evacuation System (TRAC2ES) via the Internet. Facsimile, telephone, and Secure Internet Protocol Router Network (SIPRNet) messages are acceptable if TRAC2ES is unavailable.
- PMRC reviews the patient movement request, validates the request, and establishes an AE requirement. The validating flight surgeon, a senior physician assigned to the PMRC, is primarily responsible for this action.
- Determine the need for a CCATT (see "Special Considerations," above).
- Patient clearance
  - The local flight surgeon, working with the referring physician, determines that the patient is medically stable for

transport with the appropriate equipment and medication available for transport, then clears the patient for flight.
    - For CCATT patients, the transporting CCATT physician makes the final determination, considering the patient's ability to tolerate transport and operational issues.
- Patient movement precedence:
    - Urgent: Immediate evacuation is necessary to save life, limb, or eyesight (transport as soon as possible).
    - Priority: Prompt medical care is required and not available locally; use when condition can deteriorate and patient cannot wait for routine evacuation (transport within 24 hours).
    - Routine: Requires evacuation, but condition is not anticipated to deteriorate significantly (transport within 72 hours).

PMRC Contact Information

TRANSCOM Patient Movement Requirements Center-Americas
Scott Air Force Base, Illinois
CONUS, US Southern Command
Commercial (COMM) Telephone: (618) 256-8728 (staffed all hours, 365 days a year)
Defense Switched Network (DSN): 576-8728

TRANSCOM Patient Movement Requirements Center–West
Joint Base Pearl Harbor-Hickam, Hawaii
US Pacific Command, East Asia
COMM Telephone: (808) 448-1602/1609
DSN: (315) 448-1602/1609
Fax (DSN): (315) 448-1606
E-Mail: tpmrcp.ustranscom@us.af.mil

TRANSCOM Patient Movement Requirements Center–East
Ramstein Air Base, Germany
US European Command, US Central Command, US Africa Command
COMM Telephone: 011-49-6371-47-8040 or 2264
DSN: (314) 480-8040 or 2264
Fax (DSN): (314) 480-2345
E-Mail: tpmrc-e.3afsgz @us.af.mil

Surgery

Chapter 12

Burns

Introduction

Natural childhood curiosity and lack of supervision frequently combine to make thermal injuries a major cause of morbidity and mortality in the pediatric patient. In hostile environments, these dangers are magnified and may be accompanied by injuries secondary to blast, fragmentation, and blunt forces, resulting in visceral, neurological, and orthopedic injuries. Whether accidental or intentional, the most frequent etiologies of childhood burns are flame and scalding. Many factors contribute to the significant differences in the pathophysiology and treatment of burn injuries in children, including diminished thickness of skin and subcutaneous tissue, immaturity of immune and organ systems, difficulty establishing and maintaining intravenous (IV) access, pain management, and the psychological ramifications of hospitalization, parental separation, physical disability, and disfigurement.

General Considerations

- Most burns occur in the home.
- Scalding is the most common etiology.
- Flame burns cause the highest incidence of full-thickness injuries and are associated with the highest morbidity and mortality.
- Metabolic responses include:
  - increased protein and muscle catabolism,
  - gluconeogenesis and hyperglycemia,
  - decreased insulin responsiveness,
  - increased plasma catecholamines (especially norepinephrine), and
  - increased heat production (basal metabolic rate).

Pathophysiological Considerations

- Children's increased surface-area-to-body-weight ratio results in increased evaporative water loss.
- Decreased skin thickness and decreased insulating fat result in increased heat loss.
- Children have a narrower airway than adults, and because resistance is inversely proportional to the fourth power of the radius, critical airway compromise may result from even minimal edema.

Point-of-Injury Care

- Key steps in first aid for pediatric burn patients are as follows.
  - Fire: stop the burning process.
  - Chemical: remove contaminated clothing; lavage with copious quantities of water.
  - Electrical: remove the patient from contact with the electrical current.
- Ensure airway patency.
- Prevent hypothermia by covering the patient with a clean, dry sheet or thermal blanket, increasing room temperature, and providing warm IV fluids.
- Establish IV or intraosseous access and begin fluid resuscitation with Ringer's lactate.
- Conduct a primary ("ABCDE") survey, assessing the following:
  - **a**irway,
  - **b**reathing,
  - **c**irculation,
  - **d**isability, and
  - **e**xposure/**e**nvironmental control.
- Conduct a secondary survey to uncover coexistent injuries.

History

- Use the mnemonic "AMPLE" when taking history.
  - **A**llergies
  - **M**edications
  - **P**ast illnesses
  - **L**ast meal
  - **E**vents/**E**nvironment

Head-to-Toe Physical Examination

- Examine every orifice.
- Conduct a complete neurological examination.
- Run special diagnostic tests as needed.
- Reevaluate.

Initial Treatment

- Administer supplemental oxygen.
- Place a nasogastric tube in patients with burns over more than 20% total body surface area (TBSA) due to the high incidence of ileus.
- Place a Foley catheter.
- Monitor with electrocardiogram and pulse oximeter.
- Check hourly vital signs; monitor fluid input and output.
- Obtain chest radiographs of all intubated patients and those with suspected inhalation injury.
- Initial laboratory tests include the following:
  - complete blood count,
  - electrolytes,
  - blood urea nitrogen/creatinine,
  - blood glucose,
  - urinalysis, and
  - blood type and screen.
- Consider checking arterial blood gases and carboxyhemoglobin levels, if available (inhalation injury should be suspected in all burns incurred in closed spaces).
- Keep the patient warm by infusing warm IV fluids, elevating room temperature, and minimizing patient exposure to lower environmental temperature.
- Administer tetanus immunization. If immunization status is in doubt, give both tetanus toxoid and tetanus immune globulin.
- Encourage ulcer prophylaxis.
- Systemic antibiotics are not indicated except for treating proven infection.

Determining Burn Depth

First Degree

- First-degree burns involve the epidermis only (eg, sunburn; Figure 12-1).
- They are erythematous, painful, and do not blister.
- They are not included in TBSA calculation.

Second Degree ("Partial Thickness")

- Superficial partial-thickness burns involve injury to the epidermis and superficial dermis; are erythematous, painful, and characterized by intact or ruptured blisters; and heal spontaneously within 1 to 2 weeks, usually with minimal scarring (Figure 12-2).
- Deep partial-thickness burns involve injury to the epidermis and deeper layers of the dermis (with some remaining viable dermis) and are whiter and less erythematous. As the depth into the dermis increases, deep partial-thickness burns may appear mottled. Epidermal appendages (hair follicles, sweat, and sebaceous glands) serve as the source of regenerating epidermal cells following a burn, as well as a source of bacterial contamination.

Third Degree ("Full Thickness")

- Third-degree burns involve epidermis and full thickness of the dermis (Figure 12-3).
- These burns always require skin grafting.
- They are painless because nerve endings are destroyed.
- They are whitish-gray or waxy to black and leathery in appearance; dermal elements (hair, capillaries, nerves) are destroyed.
- Distinguishing between deep partial-thickness burns and full-thickness burns may initially be difficult.
- Deep partial-thickness burns often require 3 to 4 weeks to heal.
- The degree of scarring is related to the length of time needed for reepithelialization; deep partial-thickness burns that take



Figure 12-1. First-degree burn.

longer than 3 weeks to heal should be excised and grafted to mitigate against hypertrophic scarring and improve long-term cosmesis.



Figure 12-2. Second-degree burn.

Fourth Degree

- Fourth-degree burns involve the destruction of epidermis, full-thickness of the dermis, and subdermal structures (eg, muscle, bone, or tendon; Figure 12-4).



Figure 12-3. Third-degree burn.

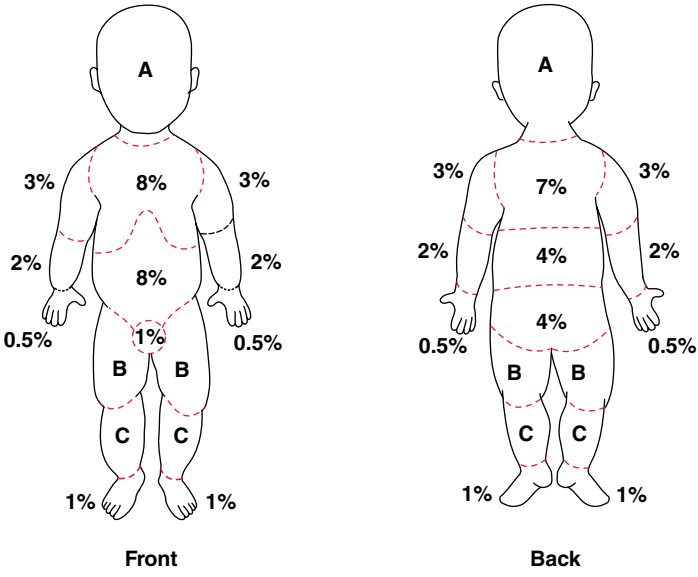


Figure 12-4. Forth-degree burn.

- Fourth-degree burns are typically associated with electrical burns.

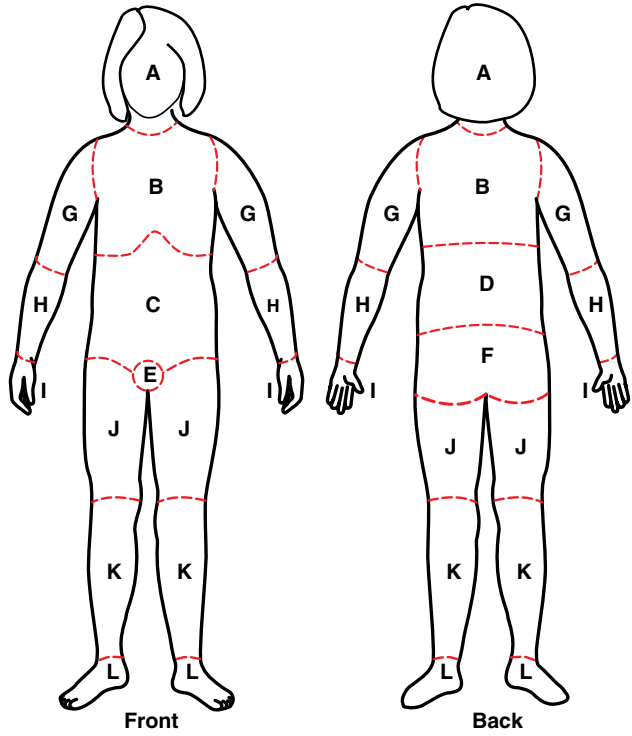
Estimating Burn Surface Area

- The pediatric modification of the adult "rule of nines" takes into consideration that a child's head size is relatively larger, compared to the torso and extremities, than an adult's; the increased ratio of the surface area of the head to TBSA decreases as age increases.
- A child's palm approximates 1% TBSA; this estimation can be useful for calculating splotchy patterned burns.
- A modified Lund and Browder chart can be used for calculations in infants (Figure 12-5) and children less than 10 years old (Figure 12-6).



Area	Age 0	1y	5y	10y	15y	Adult
A = half of head	9½	8½	6½	5½	4½	3½
B = half of one thigh	2¾	4¼	4	4½	4½	4¾
C = half of one leg	2½	2½	2¾	3	3¼	3½

Figure 12-5. Infant burn size.



Area	Age 1y	5y	10y	15y
A = half of head and neck	8½	6½	5½	4½
B = half of chest	7	7	7	7
C = abdomen (front)	6	6	6	6
D = abdomen (back)	5	5	5	5
E = perineum	1	1	1	1
F = buttocks	5	5	5	5
G = half of arm	2½	2½	2½	2½
H = half of forearm	2	1½	2	2
I = half of hand	1½	2	1½	1½
J = half of thigh	3	4	4	4½
K = half of leg	2½	4	3	3
L = half of foot	1½	1½	1½	1½

Figure 12-6. Older child burn size.

Inhalation Injury

- Always suspect inhalation injury when a burn occurs in a closed space (Figure 12-7).
- Physical findings of inhalation injury include:
  - singed nasal hair and eyebrows,
  - carbonaceous sputum,
  - increased carboxyhemoglobin,
  - hoarseness,
  - wheezing,
  - bronchorrhea, and
  - altered mental status.
- Diagnose using bronchoscopy to determine the extent and severity of injury to the tracheobronchial tree.
- Indications for intubation include compromised upper airway patency, a need for ventilatory support as manifested by poor gas exchange or increased work of breathing, or compromised

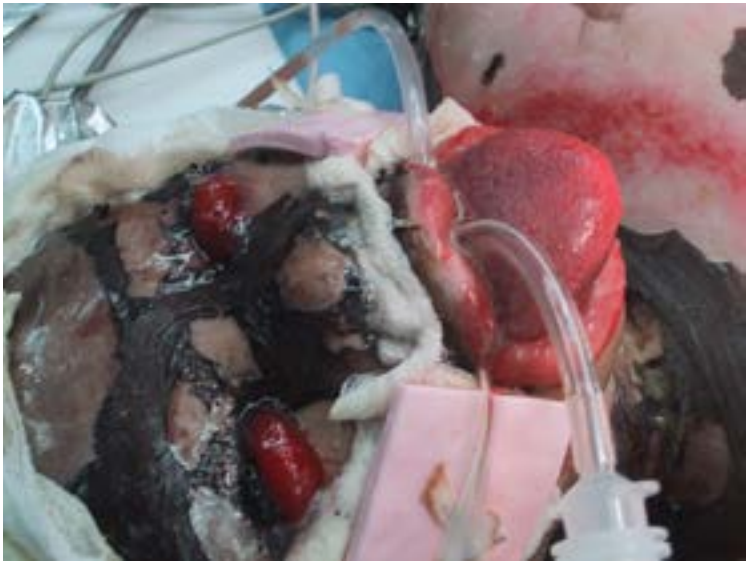


Figure 12-7. Severe facial burn showing difficult reintubation and physical signs of inhalation injury.

mental status (Glasgow Coma Scale score ≤ 8). Because of the small diameter of the pediatric airway and the expectation of progressive narrowing due to edema and bronchospasm, it is important to establish a definitive airway early on. Suspected or documented pneumonia should be treated with appropriate antibiotics, vigorous pulmonary toilet, and toilet bronchoscopy, if needed.

- Carbon monoxide toxicity is the leading cause of death in patients with inhalation injury.
  - Carboxyhemoglobin levels and their associated symptoms are as follows:
    - Less than 20%: no symptoms.
    - 20% to 30%: headache, nausea.
    - 30% to 40%: altered mental status.
    - 40% to 60%: unconsciousness.
    - More than 60%: death.
  - Carbon monoxide toxicity should be suspected when there is persistent metabolic acidosis, despite adequate volume resuscitation.
  - Treatment: 100% oxygen should be administered via a high-flow, nonrebreathing mask to all patients suspected of having inhalation injury.

Guidelines for Hospitalization or Transfer to a Burn Center

- Second- or third-degree burns over more than 10% TBSA in patients less than 10 years old.
- Third-degree burns over more than 5% TBSA.
- Full- or partial-thickness burns involving the face, eyes, ears, perineum, hands, or feet.
- Inhalation injuries.
- Electrical injuries.
- Chemical injuries (especially those involving white phosphorus).

Fluid Resuscitation

- Children with burns over more than 20% TBSA require formal IV fluid resuscitation.
- An indwelling urinary catheter is required to accurately measure the adequacy of resuscitation.

- Avoid fluid boluses unless the patient presents with hypotension secondary to hypovolemia.
- Calculating resuscitation requirements
  - In the first 24 hours (modified Parkland formula):

total 24-hour volume = (3 cc Ringer's lactate) × (weight in kg) × (%TBSA).

Half of this volume is infused over the first 8 hours (calculated from the time of burning, not from when the patient actually arrives at the treatment facility). The remaining half of the calculated 24-hour volume is infused over the next 16 hours.

- These calculations are only an initial estimate; reassess the fluid rate every hour and titrate as appropriate to achieve an hourly urine output of 1 cc/kg/h in toddlers and 2 cc/kg/h in infants.
- Children weighing less than 30 kg should receive D_5 Ringer's lactate at a standard maintenance rate (4 cc/kg/h for the first 10 kg, 2 cc/kg/h for the next 10 kg, 1 cc/kg/h for weight over 20 kg) in addition to their calculated resuscitation requirement.

  - 24 to 48 hours after burn:
    - At the 24th hour, decrease IV fluid rate to approximately 1 to 1.5 × maintenance.
    - For burns over more than 30% TBSA, infuse 5% albumin at a rate of:
      - 30% to 40%: 0.3 cc/kg/% TBSA burn for 24 hours.
      - 50% to 70%: 0.4 cc/kg/% TBSA burn for 24 hours.
      - 80% to 100%: 0.5 cc/kg/% TBSA burn for 24 hours.
    - Colloid administration may be initiated early if resuscitation volumes exceed estimates before 24 hours.
  - After 48 hours:
    - Diuresis will usually commence at this time.
    - Administer D_5 Ringer's lactate at a maintenance rate.
    - Monitor daily body weight, daily "ins and outs," urine-specific gravity, serum electrolytes, blood urea nitrogen/creatinine, and complete blood count. Supplement electrolytes and free water as indicated.

- Note: it is critically important that intake and output volumes are recorded every 30 to 60 minutes on a burn resuscitation flow sheet.

Managing Minor Burns

- Goals of treatment are to minimize pain, superficial infections, wound drainage, and prolonged convalescence.
- Small burns may initially be covered by a cloth cooled with saline solution.
- Ice should never be applied directly to a burn.
- Intact blisters should be left unbroken unless they are at flexion creases; ruptured vesicles should be debrided and the area cleansed gently.
- Partial-thickness injuries may be treated with 1% silver sulfadiazine cream or by application of a fine-mesh gauze impregnated with petroleum jelly.
- Tetanus immunization should be given as indicated by immunization history.
- Nonsteroidal antiinflammatory agents may reduce pain.
- If the patient has evidence of group A streptococcal disease, give penicillin (50,000 units/kg/24h, divided every 6 h oral or IV) to prevent colonization of the burn.

Burn Wound Care

- Provide adequate IV (not intramuscular or subcutaneous) analgesics or conscious sedation for wound debridement and dressing changes.
- Devitalized skin, foreign bodies, and ruptured blisters should be debrided.
- Cleanse wounds with surgical soap.
- Apply topical agents twice a day, such as:
  - 1% silver sulfadiazine cream (may cause neutropenia).
  - 10% mafenide acetate cream (a carbonic anhydrase inhibitor that may cause metabolic acidosis and compensatory hyperventilation).
  - 0.5% silver nitrate solution (may cause decreased serum sodium, resulting in seizures, methemoglobinemia, and indelible black staining).

- Silver-impregnated dressings may be changed every 48 hours, rinsed, and reapplied on the same patient.
- Treat facial burns with antibiotic ointment to avoid ocular irritation.
- Treat burns to the external ear with mafenide acetate cream.

Circumferential Extremity Burns

- The eschar of circumferential full-thickness and deep partial-thickness burns may result in vascular compromise as resuscitation proceeds.
- Delta pressure = diastolic blood pressure – measured compartment pressure. A delta pressure less than 30 mmHg is indicative of a compartment syndrome.
- Extremity escharotomy is indicated for clinical symptoms of ischemia (five Ps: pain, pallor, paresthesias, paralysis, pulselessness) or for progressive firmness of an extremity.
- Treat with emergent escharotomy, preferably performed at the bedside using electrocautery.
  - Incise the eschar longitudinally through the medial and lateral aspects of the extremity down to the subcutaneous fat, which should bulge into the wound if adequately incised (Figure 12-8).
  - Arterial pulse should immediately return.
- Failure to adequately apply compartmental decompression may necessitate a fasciotomy (Figure 12-9), especially with high-voltage electrical burns. This procedure is generally performed in the operating room but can be effectively performed in the intensive care unit if necessary.

Circumferential Chest Wall Burns

- A child's respiratory efforts may become rapidly exhausted by the edema and restriction of a circumferential chest wall burn.
- Decreased compliance may impair oxygenation and ventilation, which are indications for chest wall escharotomy (Figure 12-10). Perform a chest wall escharotomy by incising the chest along the anterior axillary lines bilaterally, extending onto the abdomen, with transverse bridging incisions across the chest.



Figure 12-8. Upper extremity escharotomy.

Surgical Burn Treatment

- Early excision and grafting are effective in decreasing morbidity and improving the mortality rate of extensive full-thickness burns. The goal should be to excise the wound within the first week following injury, but this is not always practical in an austere environment and patients should be transferred to a facility with burn care resources and expertise.
- Preoperatively, patients must be hemodynamically stable and in optimal acid–base, fluid, and electrolyte balance.
- Intraoperative hypothermia should be anticipated and prevented.
- Adequate blood products must be available before excision and grafting can be considered.
- A prophylactic dose of a first-generation cephalosporin antibiotic may be used.
- It is extremely important to maintain the patient's body temperature at all times.

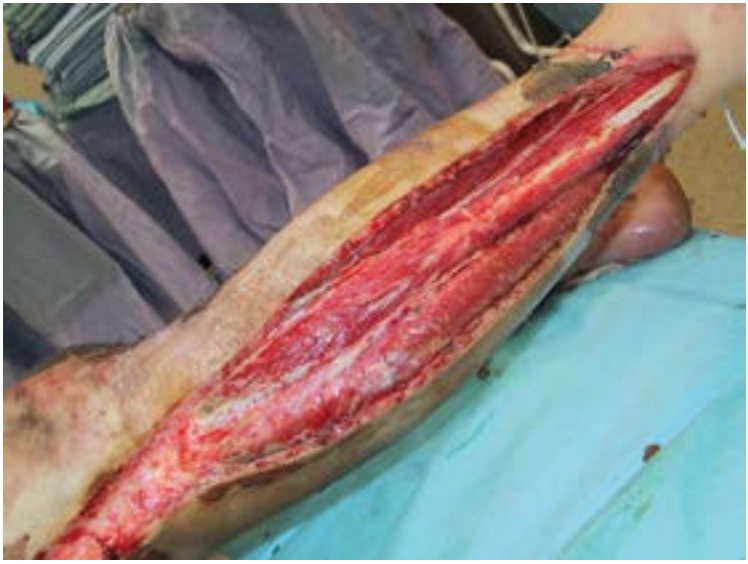


Figure 12-9. Fasciotomy.

  - Raising the temperature of the operating room is the most effective way to achieve this.
  - On-table patient warming devices can also be used.
- Tangentially excise burn eschar in a progressive fashion down to viable tissue using an electric or air-driven dermatome or freehand knife (eg, Weck). Bleeding may be minimized by careful operative planning, subeschar dilute epinephrine clysis, or use of tourniquets.
- Harvest meshed autografts from donor sites. Graft thickness varies in pediatric patients.
  - Infants: 0.008 to 0.010 inch.
  - Children: 0.010 to 0.012 inch.
  - Teenagers: up to 0.012 inch.
- Carefully apply appropriate wound dressings to prevent dislodgment of crucial skin grafts.
- Donor sites can be dressed with occlusive or nonocclusive dressings.



Figure 12-10. Torso escharotomy.

- Burn excision results in significant blood loss; the equivalent of 4 units of packed red blood cells (40 cc/kg) should be available for each 10% TBSA excision.

Electrical Burns

- Low-voltage injuries result from sources of less than 1,000 volts and include oral injuries from biting electrical cords, outlet injuries from placing objects into wall sockets, and injuries from contacting live wires or indoor appliances.
- High-voltage injuries are caused by sources of more than 1,000 volts and result from contact with a live wire outdoors or from being struck by lightning.
- Children who have sustained high-voltage electrical injury require admission to the hospital and cardiac monitoring, serial electrocardiography, urinalysis, and determination of creatine kinase and urine myoglobin levels.

- If urine is dark red, assume myoglobinuria (Figure 12-11) and initiate treatment to avoid renal tubular injury. Increase fluid administration to produce a urine output of 2 cc/kg/h. If pigment does not clear, administer 1 g/kg of mannitol IV and add mannitol to IV fluids.
- Treat metabolic acidosis in a normovolemic patient with sodium bicarbonate to alkalize the urine and increase myoglobin solubility.
- Follow renal function and serum electrolytes.
- Perform appropriate radiographic examinations to exclude concomitant long-bone and spine injuries.
- Myoglobinuria should be treated aggressively with IV hydration, osmotic diuretics, and urine alkalinization to avoid renal failure.
- Extremities must be monitored carefully for compartment syndrome development, which would necessitate fasciotomy.
- The definitive treatment for myoglobinuria is surgical debridement of dead muscle.

Chemical Burns

- The cornerstone of initial management for chemical burns is copious irrigation with water.
- Alkali burns may require several hours of lavage.
- Resuscitate and manage patients with chemical burns in the same manner as those with thermal burns.
- White phosphorus ("WP," "Willy Peter") is an incendiary chemical used in ordnance, such as hand grenades and mortar rounds, and has some particularly nasty attributes.
  - Incandescent particles of white phosphorus cast off by the initial explosion can produce extensive, deep, second- and third-degree burns. It adheres to the skin and continues to burn at extremely high temperatures unless deprived of oxygen or until it is completely consumed.
  - Terminate further white phosphorus oxidation by irrigation or by placing saline-soaked or water-soaked pads on areas of exposure. Remove contaminated clothing because it may reignite and cause extended and worsened burns.



Figure 12-11. Heavily pigmented urine.

Pain Management

- Pain and anxiety management are critical to the care of burned children.
- Initially, IV morphine should be used in small amounts and titrated to the child's physiological state.
- Analgesic agents are most effective when given on a regular schedule (rather than as needed).
- Generous analgesia or conscious sedation should be used before dressing changes and wound debridement or other painful procedures.
- A bowel regimen, including both a stimulant and a stool softener, should be maintained as long as the child is being administered opioid-derived analgesics.
- Benzodiazepines alleviate the many psychological stresses impacting injured children.
- Use diphenhydramine to treat severe pruritus in children with healing second-degree burns.

Nutrition

- Nutritional support should be started as soon as possible after injury, preferably via the enteral route.
- If patients cannot ingest adequate calories, a nasoduodenal feeding tube should be placed and isoosmolar feedings initiated.
- Estimated protein requirements are 3 g/kg/day.
- The daily caloric requirements of pediatric burn patients can be estimated using the Curreri formula:
  - Age 0 to 1 years: basic metabolic requirements + 15 kcal/%TBSA burn.
  - Age 1 to 3 years: basic metabolic requirements + 25 kcal/%TBSA burn.
  - Age 4 to 15 years: basic metabolic requirements + 40 kcal/%TBSA burn.

Rehabilitation

- Burns traversing joints must be treated with passive and active range-of-motion exercises during the healing process.

- Burned extremities should be splinted with the joints in the position of function at night.
- Attention to occupational and physical therapy is necessary to ensure optimal results.
- Burns requiring more than 2 weeks to heal and all grafted burns should ideally be treated for 1 year with compression garments that apply approximately 30 mmHg of pressure, which decreases the formation of hypertrophic scars.

Chapter 13

Neurosurgery

Managing pediatric neurotrauma at medical treatment facilities (Roles 1 to 3) requires especially close coordination by providers and administrators within the military healthcare system. Caring for pediatric neurotrauma patients is resource intensive. Patients frequently require prolonged mechanical ventilation, extensive rehabilitation, specialized nursing and medical expertise, and invasive physiologic monitoring. Few facilities in the developing world are capable of providing the requisite level of care, and coalition healthcare providers are often unprepared for such limitations. It is essential to assess facility capabilities and address postresuscitation and posttreatment patient flow *prior* to the arrival of pediatric casualties. Patient transfer to hospitals within a country or to another country are often complicated by operational and diplomatic considerations. Failure to make these assessments will result in poor patient outcomes, increased stress on healthcare providers, and potential erosion of relationships with local host-nation residents.

Non-neurosurgeons assigned to Role 3 facilities should receive training in the basic tenets of performing emergency craniotomies prior to deployment. Cranial surgery should only be performed by non-neurosurgeons in the most dire circumstances, and ideally after consultation (via telephone, radio, Internet) with a qualified neurosurgeon, if at all feasible. Nonemergent and elective neurosurgical procedures should not be performed. All general surgeons should be familiar with the array of nonoperative treatment regimens for head trauma discussed in this and other chapters of this book. Unforeseen complications are potentially devastating in craniotomies performed for trauma, and due to the limitations of resources and surgical expertise in austere environments, are often accompanied by significant morbidity, mortality, and recurrence of the original pathology.

Considering the available tiered military medical resources, host-nation resources, and logistics, the best medical management with or without expedited transfer is often the optimal treatment solution.

Head Injury in the Pediatric Patient

- Anatomical, physiological, cognitive, and social variances between adult and pediatric patients influence evaluation and treatment.
- Accurate neurological assessment is essential for appropriate patient triage and guides further management.
  - The validity of the Glasgow Coma Scale (GCS) is compromised in children because it is difficult to accurately categorize their verbal and motor responses. Age-appropriate modifications should be used to determine the GCS score (Table 13-1).
  - The Infant Face Scale (Table 13-2) is a validated clinical tool with a high degree of interrater reliability; it is a modified GCS for children.

Table 13-1. Glasgow Coma Scale

Function	Score
Eye Opening	
Spontaneous	4
Verbal stimulation	3
Painful stimulation	2
None	1
Motor	
Spontaneous and purposeful	6
Withdraws to touch	5
Withdraws to pain	4
Flexion	3
Extension	2
None	1
Verbal	
Coos and babbles	5
Irritable cries	4
Cries in response to pain	3
Moans in response to pain	2
None	1

- Triage decisions in pediatric patients in theater are difficult and can be emotionally charged.
  - Although pediatric patients with neurological injuries are more likely to have favorable long-term outcomes than adults with similar injuries, their care is impacted by limited resources in theater.
  - The decision to initiate treatment as opposed to provide palliative care for an injured child is a sobering but necessary aspect of neurotrauma care in an austere environment.
  - Several factors influence whether to proceed with treatment, including:
    - a facility's capabilities,
    - the physicians' and nurses' level of expertise,
    - options for later evacuation to military facilities with enhanced capabilities or to a host-nation healthcare facility,

Table 13-2. Infant Face Scale Modifications to Glasgow Coma Scale

Function	Score
Best Motor Response	
Spontaneous, normal movements	6
Hypoactive movements	5
Nonspecific movement to deep pain	4
Abnormal, rhythmic, spontaneous movements	3
Extension, either spontaneous or to pain	2
Flexion	1
Best Verbal Response	
Cries spontaneously to handling or pain, alternating with quiet wakefulness	5
Cries spontaneously to handling or minor pain, alternating with sleep	4
Cries to deep pain only	3
Grimaces only to pain	2
No facial expression to pain	1

Data source: Durham SR, Clancy RR, Leuthardt E, et al. CHOP Infant Coma Scale ("Infant Face Scale"): a novel coma scale for children less than two years of age. *J Neurotrauma*. 2000;17(9):729–737.

    - operational factors,
    - clinical factors, and
    - physiologic stability. Abundant literature confirms poor neurological outcomes in patients following prolonged periods of hypotension or hypoxia; palliative care should be strongly considered for patients in these circumstances.
- GCS and Infant Face Scale scores correlate well with neurological outcome and are accurate in normotensive, nonhypoxic patients with no pharmacologic agents compromising their examination.
    - After physiological stabilization, consider reversing sedation and neuromuscular blockade to facilitate a comprehensive neurological assessment.
        - See Broselow tape for reversal-agent dosing.
        - Muscle relaxation reversal should be confirmed with a peripheral nerve stimulator.
        - A typical reversal regimen consists of neostigmine (50 μg/kg), glycopyrrolate (10 μg/kg), naloxone (10–20 μg), and flumazenil (10 μg/kg).
    - Patients with GCS scores greater than 8 will often benefit from treatment; when resources are available, they should be treated aggressively.
    - Patients with GCS scores of 6 to 8 inhabit a "gray zone" and may proceed to treatment or palliative care, depending on additional clinical considerations and resource availability.
    - Patients with GCS scores less than 5 will rarely benefit from treatment in a forward environment, and expectant management should be considered.

Pupillary Reactivity

- Findings of a pupillary examination convey important information about the function of the eye and cranial nerves II and III.
- Pupillary function can be impaired by several medications, including intravenous atropine (often used for resuscitation).
- Pupillary function is not impaired by muscle relaxants.
- In the absence of penetrating injuries to the globe, bilateral mydriasis (large, nonreactive pupils) is a strong predictor

of poor neurological outcome; treat patients with bilateral nonreactive pupils expectantly.

- Unilateral pupil dilation may result from direct trauma to the globe, orbit, or cranial nerves. Unilateral pupil dilation can indicate impending herniation and should be considered in concert with other clinical factors.
- A computed tomography (CT) scan is important when determining the salvageability of neurological patients. The following two findings are the most likely to determine patient salvageability:
  - Midline shift: easily measured by dropping a line from the anterior and posterior insertion of the falx cerebri.
    - Midline shift allows for quantification of intercompartmental shift.
    - A shift exceeding 5 mm is worrisome; a shift in excess of 1 cm portends a poor prognosis.
  - Patency of basal cisterns (Figure 13-1): the basal cisterns, small-volume spinal fluid spaces at the base of the brain, are visible on nearly any CT scan of the head.
    - Anteriorly, basal cisterns are shaped like pentagons, and posteriorly like smiles.
    - When patent, basal cisterns indicate low intracranial pressure (ICP) and increased likelihood of salvageability.
    - When basal cisterns are absent, the patient's prognosis is poor.

Medical Management

Hypoxia and Hypotension

Avoiding hypoxia and hypotension in the acute phases of traumatic brain injury (TBI) management should be the primary goals of the treating team.

- Using corticosteroids for ICP management in TBI patients has not been shown to have therapeutic benefit and is not advised.
- Avoid excessive hyperventilation; maintain partial pressure of arterial carbon dioxide ($PaCO_2$) at 35 to 40 mmHg. Extreme hypocarbia results in diminished cerebral blood flow and is detrimental to neurologic outcome.

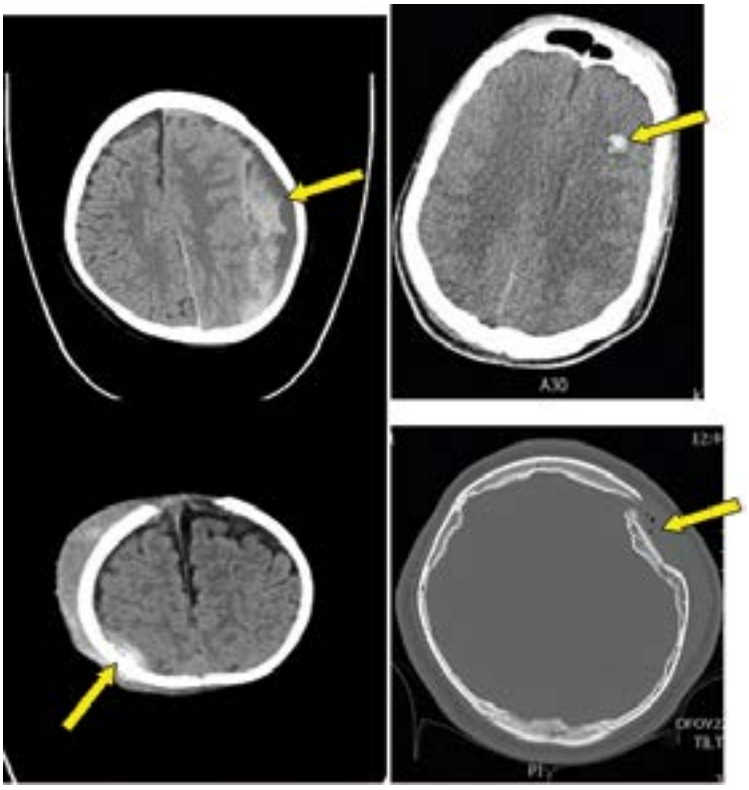


Figure 13-1. Computed tomography scans of some common injuries seen in pediatric neurotrauma. (**a**) Subdural hematoma. (**b**) Small intraparenchymal hematoma. (**c**) Small epidural hematoma in an infant. (**d**) Depressed skull fracture.

Seizure Prophylaxis

Seizure prophylaxis (Figure 13-2) is appropriate in the first week following injury to minimize the deleterious effects of increased cerebral blood flow (accompanying a generalized seizure) in patients with impaired intracranial compliance.

- Phenytoin should be used prophylactically for 7 days to reduce the incidence of posttraumatic seizures in patients with severe TBI.

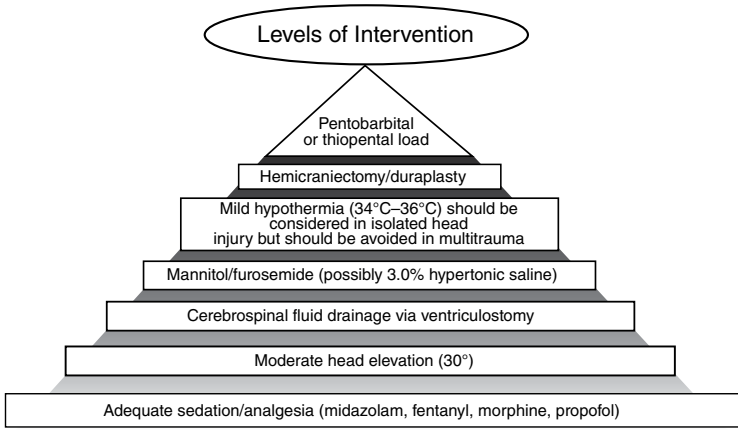


Figure 13-2. Levels of intervention in neurological injury.

- Loading dose: 15–20 mg/kg or an equivalent dose of fosphenytoin.
- Maintenance dose: 5 mg/kg/day divided twice or three times daily.

- Recognize that unexplained tachycardia in a paralyzed patient may represent seizure activity.

Intracranial Pressure Monitoring

- ICP monitoring should be strongly considered in infants and children with severe TBI (GCS score ≤ 8).
  - Additionally, the treating physician may consider ICP monitoring in a less severely brain-injured child when reliable serial neurologic examinations may not be obtainable (eg, during prolonged periods of sedation or anesthesia).
  - In situations where ICP monitoring is not achievable, alternative strategies are as follows.
    - Use hyperosmolar therapy (5–6 cc/kg of 3.0% hypertonic saline) to treat to a predetermined level of hypernatremia (ie, Na 145–160 mEq/L).
    - Use clinical cues to guide hyperosmolar therapy, such as

    - radiographic evidence of intracranial hypertension (effaced sulci or cisterns or midline shift),
    - a bulging or tight fontanelle, or
    - signs of neurologic deterioration.
- Prior to deployment, non-neurosurgeons should receive predeployment training for the indications, procedure, use, and risks of ICP monitoring devices before attempting placement in an austere environment. The following is a cursory overview for the well-trained provider.
    - A patent fontanelle does not preclude elevated ICP.
    - There is no accurate, noninvasive means of determining ICP, though military research is pursuing some promising technologies.
    - Parenchymal monitors, available through the military supply system, accurately measure ICP.
    - Parenchymal monitors are easier to place and carry a lower infection risk, but provide no means of directly treating ICP.
    - Parenchymal monitors may be placed at a depth of 1 to 2 cm, regardless of the patient's age.
    - Parenchymal monitors need to be zeroed before placement and experience a drift of up to ± 1 mmHg per day.
- Ventriculostomy catheters (Figure 13-3) also accurately measure ICP and are available in the military supply system. Placing a ventricular catheter is much more difficult than placing a parenchymal monitor and carries a higher risk of morbidity. Even the most seasoned neurosurgeon can be challenged with ventricular catheter placement in a patient with small ventricles or altered anatomy.
    - Ventriculostomy catheters allow treatment of elevated ICP by permitting intraventricular cerebrospinal fluid (CSF) drainage.
    - For ventricular catheters, antibiotic prophylaxis with a second- or third-generation cephalosporin should be considered, and periodic routine CSF sampling should be performed.
- General anatomic guidelines for placing ICP monitors are as follows (Figure 13-4).

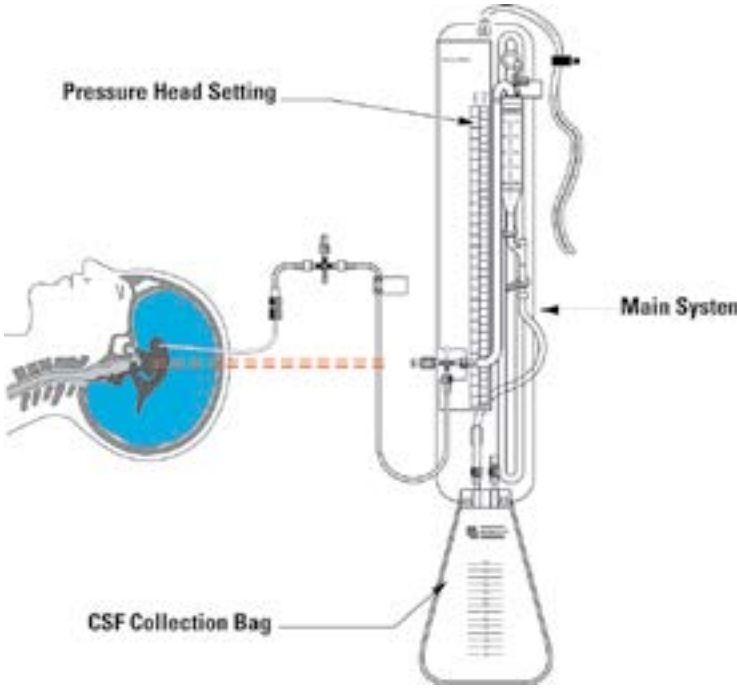


Figure 13-3. Schematic of ventriculostomy setup. Dashed red line represents the zero point of the system. Collection buretrol is set at desired height above the external auditory canal.
CSF: cerebrospinal fluid
Drawing courtesy of: Medtronic Neurosurgery, Goleta, California.

- Begin at an entrance point approximately 10 to 12 cm from the glabella posteriorly and 3 cm lateral to midline. This should correspond to a point near the coronal suture and in the mid-pupillary line. For infants, the anterior fontanelle may be used instead of a cranial trephination, provided the entry site is a minimum of 2 cm off the midline.
- Trephination of the calvarium should be performed in the same trajectory as placement of the catheter. The trajectory for catheter insertion is toward the ipsilateral medial canthus in the coronal plane and toward the tragus in the sagittal plane. This should approximate a trajectory perpendicular to the calvarium.

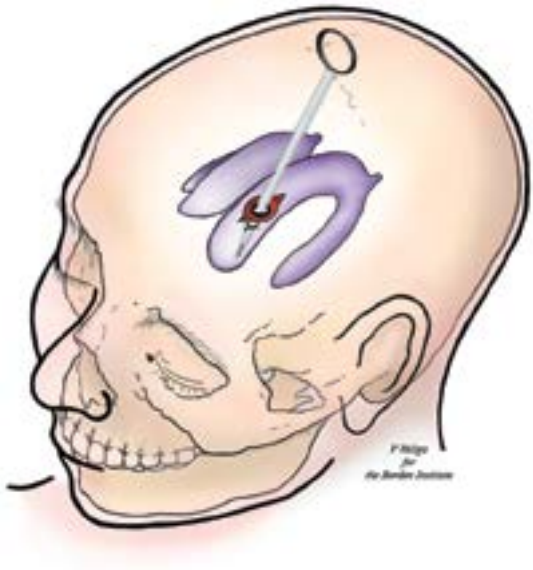


Figure 13-4. Three-dimensional rendering of the appropriate placement of a ventricular catheter into the anterior horn of the lateral ventricle.

- For parenchymal monitors, the entrance point is approximately the same, but the accuracy of the insertion point and trajectory are less critical.
- Ventriculostomy catheters lie within the ventricle at a depth of
  - 3.5 cm in infants.
  - 4 cm in toddlers.
  - 5 to 6 cm in older children and adults.
- Depth of insertion and cranial access in infants must be considered when placing ventriculostomy catheters in children.
- Drain setup is identical to that of any fluid-coupled system used in the intensive care unit, with the following exceptions.
  - The zero point for the system is the external auditory canal.
  - The system should never be attached to a pressurized flush (such as that used for an arterial line).

    - When used for drainage purposes, one method is to set the drain open at a certain height (eg, 10 cm H_2O above the external auditory canal) and record hourly output.
    - To prevent hyponatremia or hypokalemia, each milliliter of CSF output should be replaced in infants and toddlers with a milliliter of 0.9% NaCl plus 20 mEq KCl.
    - Rapidly wean the patient from CSF drainage if possible. Permanent shunts have been used in austere environments by both the military and civilian humanitarian neurosurgical organizations. The treatment team must consider the patient's ability to obtain revisions when the shunt fails to function properly.
- ICP and cerebral perfusion pressure (CPP) thresholds
    - ICP: treat sustained values of greater than 20 mmHg, with the goal of reducing below this threshold.
    - CPP is calculated by subtracting the ICP from the mean arterial pressure (MAP).
        - With the standard practice of zeroing the ICP monitor to the level of the foramen of Monro (relative to the MAP being zeroed to the atrium), true CPP will be underestimated, depending on the size of the patient and the angle of the head of the bed. Age-related variances in MAP impact CPP treatment threshold recommendations.
        - A CPP threshold of 40 to 60 mmHg should be considered. A minimum of 40 mmHg is used for infants, and the minimum is increased up to 60 mmHg for adolescents and young adults.

Medical Adjuncts

- Avoid pain and agitation in patients with head injury as this will increase ICP. Sedatives and analgesics should be chosen by the treating physician.
    - Propofol infusion is contraindicated for long-term sedation (> 24 h) in pediatric patients because of the risk of fatal metabolic acidosis (propofol infusion syndrome).
    - A single dose of etomidate (0.3 mg/kg) may be a useful adjunct in a patient with severe refractory elevated ICP.

- Low-dose thiopental may also be considered as a sedative for a patient with elevated ICP.
- 3% saline has replaced mannitol/furosemide as the preferred hyperosmolar or diuretic therapy.
  - 3% saline: bolus of 5 to 6 mL/kg can be used. Alternatively, administer an infusion ranging from 0.1 to 1 mL/kg/h. Treatments should be titrated with the goal of maintaining ICP less than 20.
  - In the absence of an ICP monitor, a target serum sodium of 150 to 155 mEq/L can be an effective treatment paradigm.
    - Higher serum sodium targets have been reported, provided isovolemia is maintained without deleterious results.
    - Hypertonic saline may also be considered in circumstances of hyponatremia caused by cerebral salt wasting syndrome, syndrome of inappropriate antidiuretic hormone (SIADH) secretion, or iatrogenic causes.

- Therapeutic hypothermia has not been validated for head injury in pediatric patients and is rarely practical in a deployed environment.
- Reduce the cerebral metabolic rate by avoiding or aggressively treating hyperthermia.
- Barbiturate coma effectively manages refractory ICP in children, but is impractical in a deployed environment. Do not use routinely.

Surgical Management

The spectrum of surgical management of pediatric head injury is broad. This chapter provides limited guidance for surgically managing head injuries; it is not a substitute for more conventional surgical education. Non-neurosurgeons should preplan and carefully consider military medical assets, transfer capabilities, and host-nation resources in their area of operation before being confronted by a surgical emergency. Ideally, predeployment training for the non-neurosurgeon, coupled with real-time remote neurosurgical consultation, is advised to address the atypical circumstance when cranial surgery by a non-neurosurgeon may be warranted.

Scalp Lacerations and Low-Velocity Penetrating Head Injuries

- Understanding the anatomy of the scalp and principles of scalp closure is essential (Figure 13-5).
- Penetrating injuries to the scalp require watertight repair to stop blood loss and prevent CSF efflux and the potential for meningitis from retrograde infection.

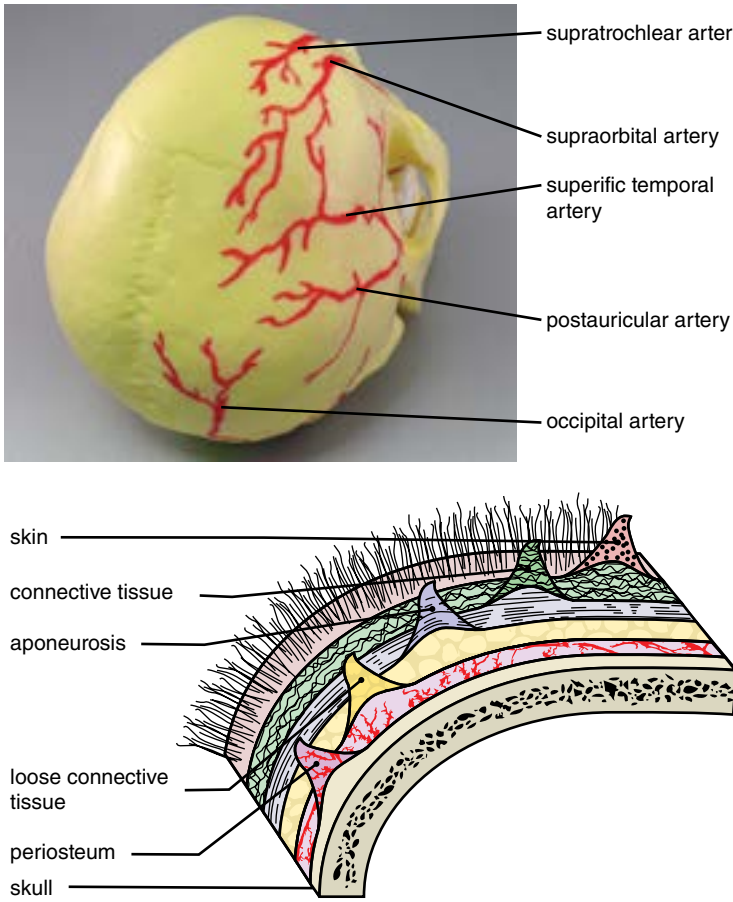


Figure 13-5. Scalp anatomy and blood supply.

- The only surgical intervention required in the majority of head-injured patients with GCS scores greater than 8 may be as simple as the following:
  - fully expose the wound by shaving the scalp,
  - conservatively debride devitalized tissue, and
  - perform layered closure of the galea, followed by the skin.
- Definitive treatment for many patients (particularly those with a GCS score ≥ 11) can be performed at facilities with limited surgical capabilities.

Craniotomy in the Pediatric Patient

- Positioning: a Mayfield headrest with pins is not appropriate for pediatric trauma patients in theater. A gel donut or cerebellar headrest (when available) helps avoid the potential for skull penetration in thinner pediatric skulls. A generous shoulder/hip roll can be used to maintain neutral neck positioning.
- Scalp incision: decreased absolute patient blood volume makes hemostasis imperative during scalp incision.
  - Lidocaine (0.5% lidocaine with epinephrine 1:100,000) is a readily available, easy means of reducing blood loss at the time of skin incision.
  - Lidocaine toxicity limits dosing to less than 7.5 mg/kg.
    - A maximum of 5 mg/kg of lidocaine or 7 mg/kg of lidocaine with epinephrine, injected intradermally, can be used in pediatric patients (1% lidocaine = 10 mg/mL).
    - In children less than 2 years old with decreased scalp thickness, Raney clips can be applied to achieve hemostasis.
    - Alternatively, apply hemostats to the galea during opening.
    - Consider extending the scalp incision through the dermal appendages only and complete the opening with monopolar electrocautery.
    - A needle-tipped Bovie on settings of 7 cut, 12 cauterize works well.
    - Dural closure is rarely required and often needlessly prolongs anesthesia for damage-control surgery.

- Onlay dural grafts are readily available and are the preferred tools in this setting for separating the brain from the scalp.
- Onlay repairs are effective in nearly all cases where the galea and scalp have been properly closed.

Bone Flap Preservation

- Pediatric neurotrauma patients have limited options for reconstructive surgery following recovery in theater (Figure 13-6).
- In acute injury, the bone flap is rarely replaced in the head at the time of surgery.
- Autologous "storage" of a flap that is not grossly contaminated is possible. At the time of cranial surgery, prepare the abdomen for subcutaneous bone flap placement. The right lower quadrant is preferred to preserve the left upper quadrant for possible gastronomy tube placement.
- The bone flap must occasionally be bisected and stacked to accommodate an expansive hemicraniectomy flap.
- The bone flap has the potential to become infected during the patient's hospitalization or following discharge.
- Bone flap replacement may be considered 3 to 6 months after injury if follow up is possible. If not, arrangements should be made for subsequent treatment at an appropriate medical facility to the extent feasible.

Spinal Injury in the Pediatric Patient

The pediatric spine, particularly the cervical spine, differs from the adult spine both anatomically and in its response to injury. Differences are most pronounced in patients less than 9 years old, after which anatomy and injury patterns tend to parallel those of adult patients.

Anatomical and Biomechanical Differences Between the Pediatric and Adult Spine

- The pediatric spine
  - contains more elastic ligaments than the adult spine,
  - exhibits anterior wedging of vertebral bodies,

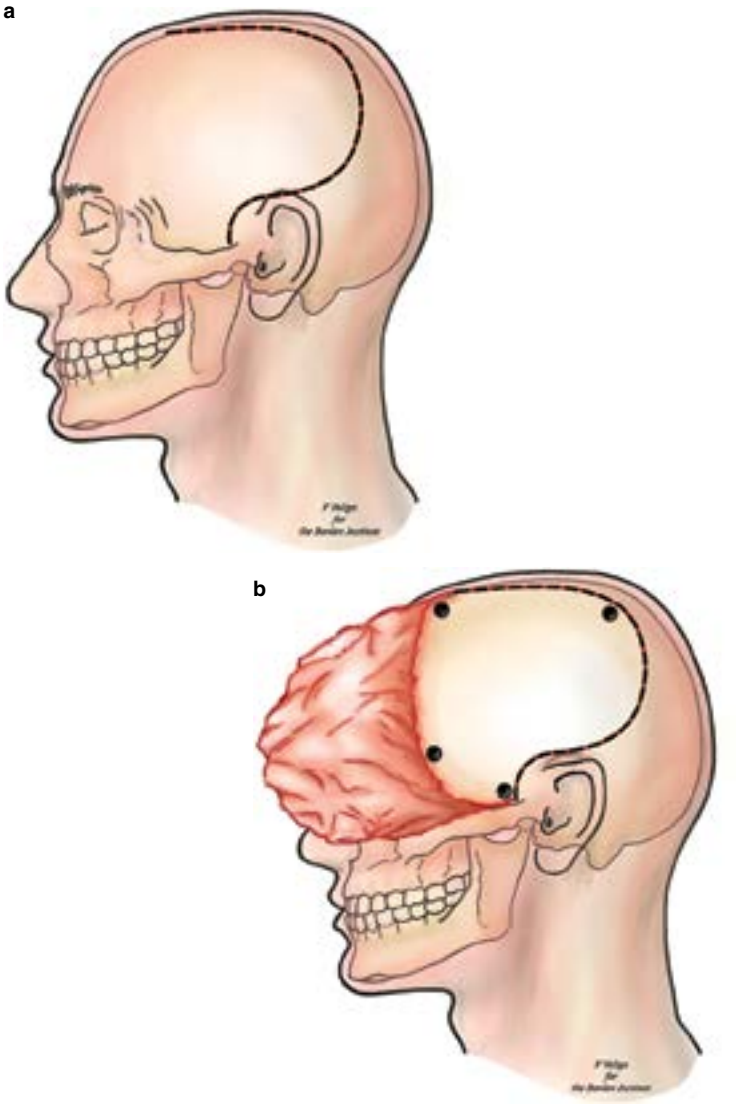


Figure 13-6. (**a**) A typical, question-mark-shaped incision in the scalp commonly used in neurotrauma. (**b**) After scalp flap rotation, several burr holes are placed within the calvarium to create a bone flap that will allow ample access to the underlying dura and brain.

    - has facet joints that are oriented more horizontally than in adults, and
    - lacks uncinate processes, making the spinal unit less stable in the cervical region.
- Children's proportionately larger heads increase the force applied to the upper cervical spine and cause neutral positioning differences compared to adults.
- The relative size of the spinal canal (which achieves near-adult cross-sectional area prior to the age of 9) presents a proportionately larger target for penetrating fragments in the thoracic and lumbar regions.

Pathophysiological Differences Between the Pediatric and Adult Spine

- The increased elasticity and proportionately larger head of a pediatric patient results in profound changes in observed injury patterns.
- Spinal fractures are relatively uncommon in pediatric patients.
- The fulcrum of the cervical spine is shifted from C5–6 in adult patients to C2–3 in infants.
    - Injuries most commonly occur between the occiput and C3 levels.
    - Disruptions of unfused ossification centers, such as the C2 synchondrosis, are common (as are ligamentous injuries at the craniocervical junction).
- Spinal cord injury without radiographic abnormality (SCIWORA) is also more common in this age group.

Radiographic Differences Between the Pediatric and Adult Spine

- There are significant differences in radiographic images and CT scans between adult and pediatric patients.
- The large proportion of cartilage in the pediatric spine, coupled with primary and secondary ossification centers, are unfamiliar to most providers.
- Standard measurements, including the atlantodental interval and anterior soft tissue thickness at C2, are increased in pediatric patients compared to adults. The normal measurements for the predens space are 1 to 3 mm in the adult, as opposed to 3 to 5 mm in the infant.

- Additional findings, such as C2–3 pseudosubluxation, also present challenges to inexperienced providers. Repositioning the head in a neutral position may help resolve the apparent finding of pseudosubluxation.
- Providers likely to encounter pediatric patients in theater should familiarize themselves with these differences and if in doubt, avoid removing cervical immobilization devices.

Transporting Pediatric Patients With Suspected Spinal Injuries

- A pediatric patient's proportionately large head size requires additional consideration at the time of transport.
- To maintain anatomical cervical lordosis and airway patency, the patient must be placed on a spine board with a bolster under the body at and distal to shoulder level, leveling the patient's face and allowing for proper spinal and airway positioning (Figure 13-7).

Medical and Surgical Management of Spinal Injuries

- Pediatric spinal injury management in current operational theaters is limited. Select US facilities in theater may have the requisite spinal instrumentation and intraoperative fluoroscopy.
- The majority of closed and penetrating injuries can be managed with resources available at facilities with less robust clinical and radiographic support.

Closed Injuries

- Management consists of restoring (near) normal anatomical alignment and immobilizing the patient.
- Gardner-Wells tongs can be used for reduction in pediatric patients as they are in adults. Less weight is typically required to achieve reduction (2 lb per level in pediatric patients, as opposed to 5–10 lb per level in adults).
- Commercial cervical collars or expedient structural aluminum malleable splints can be contoured to the patient to provide immobilization for cervical injuries.
- In the exceptional case that an appropriately sized halo vest is available, apply 6 to 8 pins at a force not to exceed 4 foot-pounds of torque.

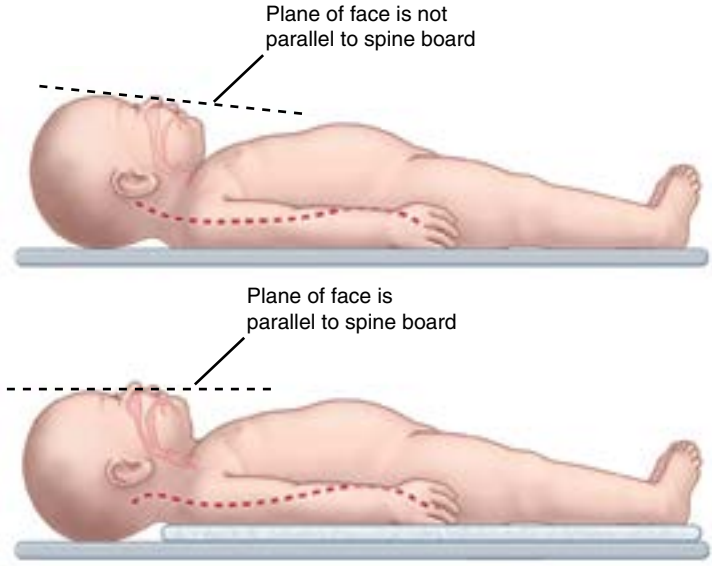


Figure 13-7. (**top**) Improper positioning of a child to maintain a patent airway. The disproportion between the size of a child's cranium and the midface leads to a propensity for the posterior pharynx to buckle anteriorly. The large occiput causes passive flexion of the cervical spine. (**bottom**) Proper positioning of a child to maintain a patent airway. Avoid passive flexion of the cervical spine by keeping the plane of the midface parallel to the spine board in a neutral position, rather than in the "sniffing position." Placement of a one-inch-thick layer of padding beneath a child's entire torso will preserve neutral alignment of the spinal column. Reproduced with permission from: American College of Surgeons. *Advanced Trauma and Life Support Student Course Manual*. 8th ed. Chicago, Ill: ACS; 2008: 230.

- Thoracolumbar fractures may be managed with 4 to 6 weeks of bed rest.
- Studies investigating the use of high-dose steroid therapy (methylprednisolone) in pediatric patients have not been performed; routine high-dose steroid therapy for pediatric spinal cord injuries is not recommended.

Penetrating Injuries

- Penetrating injuries are frequently encountered in theater.
- The absence of body armor and the proportionately large size of the spinal canal in children produce complex injuries, often traversing multiple body cavities in addition to the spinal canal.
- Antibiotic coverage is guided by the body cavities traversed and the relative cleanliness of the fragment and wound.
- Steroid therapy is inappropriate, based both on age and the penetrating mechanism.
- Spinal stability is rarely impacted by penetrating injuries.
- Most injuries are managed either with 6 weeks of bed rest for immobilization, or without positioning restrictions if upright radiographs demonstrate stability (in younger patients, sedation may be required to restrict activity).
- CSF fistula presents one of the most serious challenges in these patients.
    - If cutaneous CSF leakage is noted, or if clear fluid is noted at a high output from a chest tube following a transthoracic gunshot wound to the chest, a spinal fluid drain must be placed postoperatively, either under direct vision intraoperatively or percutaneously at the L4–5 interspace.
    - Anesthesia providers are often qualified to assist with drain placement in the absence of neurosurgical support.
    - Height-controlled drainage of 5 to 15 mL/h is usually sufficient to stop drainage through the fistula.
    - The fistula will often permanently close after 72 hours of drainage. Clamp the drain for 24 hours to ensure successful resolution of the fistula prior to removal.

Critical Aeromedical Considerations

The medical and nursing personnel accompanying a patient with a ventriculostomy catheter during air transport must have a thorough understanding of the system, and must ensure that ICP is frequently measured to preclude increases resulting from ambient barometric pressure changes. **Failure to do so has been associated with catastrophic consequences**. Patient positioning on the aircraft litter stanchions (head elevated) and location of the

patient's head (forward or aft) must also be discussed with the Air Force Critical Care Aeromedical Transport Team physician. If pneumocephaly is present, the coordinating US Air Force flight surgeon and transporting critical care physician must be made aware, so flight altitude restrictions may be considered and discussed with the aircraft commander.

Further Reading

1. Head injuries. In: *Emergency War Surgery, Third United States Revision*. Washington, DC: Department of the Army. Office of The Surgeon General, Borden Institute; 2004. Chap 15.
2. Wounds and injuries of the spinal column and cord. In: *Emergency War Surgery, Third United States Revision*. Washington, DC: Department of the Army. Office of The Surgeon General, Borden Institute; 2004. Chap 20.
3. Kochanek PM, Carney N, Adelson PD, et al. Guidelines for the acute medical management of severe traumatic brain injury in infants, children, and adolescents–second edition. *Pediatr Crit Care Med*. 2012;13(Suppl):S1–S82.

Chapter 14

Ophthalmology

Portions of this chapter previously appeared as: Ocular Injuries. In: Emergency War Surgery, 3rd United States Revision. *Burris DG, Dougherty PJ, Elliot DC, et al, eds. Washington, DC: US Department of the Army, Borden Institute; 2004: Chap 14.*

The visual sensory system of a child less than 8 to 10 years old is developing and can be irreversibly damaged by a variety of conditions if the conditions are not detected and treated early. In the US military, general ophthalmologists on active duty provide most pediatric eye care in many locations. At some facilities, optometrists may also provide nonsurgical refractive care and evaluate the eye health of pediatric patients, subsequently referring cases with more serious conditions to an ophthalmologist. Both general ophthalmologists and optometrists refer more complicated pediatric eye patients to subspecialty trained pediatric ophthalmologists. These US Army, Air Force, and Navy specialists are generally located at larger facilities, such as regional medical centers and facilities with ophthalmology teaching programs, and at all military hospitals with neonatal intensive care units. All military facilities that have ophthalmology residency programs have one or more pediatric ophthalmologists on staff.

The Pediatric Eye Examination

- History
  - Obtain a history of the present condition.
  - Gather information about birth history.
    - Prematurity may be associated with retinopathy of prematurity (ROP), hypoxic ischemic encephalopathy, intraventricular hemorrhage with secondary hydrocephalus, and ventriculoperitoneal shunts; a

failing shunt may be responsible for abducens nerve palsy ("sun-setting eyes") or papilledema.
    - Forceps delivery is associated with corneal clouding (edema of the cornea from Descemet's membrane tears).
    - Shoulder dystocia, difficult delivery, and neck traction may be associated with Horner's syndrome (ptosis, miosis, anhydrosis). Anisocoria is worse in the dark and there is mild ipsilateral ptosis.
  - General medical history should include family history (especially of strabismus and heritable eye and systemic conditions) and surgical history (ie, prior eye surgery).
- Examination
  - Observe general appearance.
  - Note head position. Observe for head tilts, face turns, and chin-up or chin-down posture. A goniometer is useful for quantifying abnormal head positions.
  - Check facial symmetry, look for gross abnormalities and size or shape disparities.
  - Determine visual acuity (one of the vital signs of eye health). Visual acuity evaluation and documentation is age dependent (Table 14-1).
    - Premature infants and neonates (up to 2 mo old) should blink in response to a bright penlight.
    - Infants (2–6 mo old) should fixate on and follow a near target, such as a human face or colorful toys.
    - In infants and toddlers (6 mo–2 ½ y old), vision should be central (eye appears properly aligned with target), steady (no nystagmus or searching movements), and maintained (eye can hold fixation for at least a few seconds when the other eye is covered and then

Table 14-1. Normal Visual Acuity by Age

Age (years)	Vision
3–4	20/30
5	20/25
6–12	20/20
12–18	20/15

uncovered; this is especially useful in the presence of strabismus).

- Preschoolers (2½–5 y old) should be able to see pictograms at 20/20 (feet) or 6/6 (meters). If the child is shy, is unable to verbally identify the pictograms, or speaks a language foreign to the examiner, placing a photocopy of the pictograms or the letters "HOTV" on a clipboard permits the patient (adult or child) to simply point and match what they see on the screen. If single optotypes are used, a one-line difference in acuity is considered significant and warrants ophthalmology referral. If the targets are presented in a linear fashion, a two-line difference is deemed significant.
- Children of school age and older should be able to see an alphabet at 20/20 (feet) or 6/6 (meters).

- Intraocular pressure (IOP; the other vital sign of eye health) is always measured indirectly (through the cornea or through the lids and cornea). If a child is unable to cooperate while conscious, IOP checks may be obtained while a child is sedated or at the onset of general anesthesia.
  - Digital (finger) method: eyes are palpated through the closed lids; annotated as normal finger tension. This method is acceptable for the majority of patients.
  - Instrument method: measured through the cornea.
    - This method is more accurate, but more frightening to the patient; therefore, it is reserved for older children or for those in whom increased IOP is suspected.
    - The Tonopen XL (Reichert Technologies, Buffalo, NY) requires a topical anesthetic, but has the advantage of giving a pressure reading with each successful tap on the cornea. The Icare Rebound Tonometer (Icare Finland Oy, Helsinki, Finland) does not require topical anesthesia, but does require several taps that are so light they are not typically perceived by the patient. Both methods require a cooperative patient.
    - Crying or active resistance may give falsely elevated IOP readings with any method.
    - IOP measurements on sleeping or eating infants tend to be very reliable.

- Binocularity is a special vital sign of pediatric eye health. Binocular vision occurs in the cerebral cortex and involves integrating the sensory input from each eye to produce a single three-dimensional image.
- Stereo vision testing (often called "depth perception" testing) is commonly used to check binocularity.
  - The Titmus (Titmus Optical Inc, Chester, VA) and Randot (Stereo Optical Company, Inc, Chicago, IL) stereoacuity tests use polarized glasses and slightly horizontally dissimilar photographs to create a three-dimensional illusion to detect the highest level of binocularity; these can be used on cooperative children as young as 2 years old.
  - With the Worth 4 Dot Test (Richmond Products, Inc, Albuquerque, NM), glasses with red and green lenses are used to view red and green lights in an otherwise dark room. This test detects a lesser level of binocularity and is used on children around 5 years old and older.
  - A base-out prism test calls for a low-power, clear prism (4–8 prism diopter power) to be brought over one eye, oriented apex toward the nose. The presence or absence of a corresponding fusional convergence movement is noted. This test can be used on children as young as 6 months old.
- Extraocular motility
  - Follow movement in lateral, medial, upward, downward, and diagonal directions of gaze. The examiner will need an assortment of fixation targets (eg, toys) to maintain the child's interest.
  - Observe for over- or under-muscle action, baseline or induced nystagmus, or strabismus.
  - Examine pupils. Check size, shape, and location of the pupils, as well as direct and consensual response to light.
  - Results are more reliable if the child's attention is diverted toward a distant target and away from the examiner's light source.
  - A finding of afferent pupillary defect requires further evaluation, especially of the optic nerve. Magnetic resonance imaging (MRI; preferred) or a computed tomography (CT) scan may be indicated.

- The examination for muscle balance is performed in primary position (face straight) at a distance and then near (14–16 inches), followed by other gaze positions as indicated (right, left, up, down, right tilt, and left tilt).
- Cover-uncover test: one eye is covered by an occluder while the examiner observes the other eye; if movement is detected, strabismus is manifest.
- Alternate cover test: an occluder is moved back and forth from one eye to the other; movement represents latent or manifest strabismus.
- Simultaneous prism cover test: an occluder is placed over the nonfixing eye while a correcting prism is placed over the dominant, better-seeing eye because the prism itself can blur the patient's vision. Putting a prism over a poorly seeing or amblyopic eye could degrade the acuity even further, making it difficult to accurately measure the angle of strabismus.
- Deviations in magnitude are measured with calibrated prisms. The endpoint is no movement on the alternate cover test or simultaneous prism cover test.

◦ External examination
- Check lid position (observe for unilateral or bilateral ptosis).
- Epicanthal folds and a flat nasal bridge are frequently associated with pseudoesotropia.
- Increased tear lake, mucoid discharge, and epiphora may be signs of nasolacrimal duct obstruction.
- Look for lid masses and lesions (eg, dermoids, molluscum lesions).
- Note telecanthus (increased distance between medial canthi).
- Check for hypertelorism, also known as telorbitism (increased distance between orbits; associated with midface abnormalities).
- Examine the anterior segment (cornea, conjunctiva, anterior chamber, and iris).
- Cycloplegic refraction is the most accurate method of determining a refractive state of the eye.

- Autorefraction is often unreliable in children; use only in adolescents.
- Manifest refraction (using phoropter) is unreliable in young children; it is easy to overestimate the power required ("over minus"); however, manual cycloplegic refraction with free-held lenses or devices (skiascopy bars) is helpful.
- Perform a retinoscopy (if the retinoscopic reflex is obscured, the visual axis is likely affected enough to produce amblyopia).
- A dilated fundus examination is best performed with an indirect ophthalmoscope set on the dim light setting.
- A posterior central fundus view is usually all that is required.
- The standard eight views of the periphery per eye is rarely indicated or tolerated by most younger children. A hand-held toy (illuminated or nonilluminated) that the child can visually track up, down, right, and left may permit better views of the peripheral retina.
- The patient may need to be evaluated under anesthesia or sedation to obtain detailed views of the peripheral retina.

Pediatric Ophthalmic Disease Diagnosis and Treatment

Nonstrabismic Conditions

- Orbital dermoid cyst
  - Orbital dermoid cysts are most commonly located along the superior-temporal orbital rim. They are occasionally attached by a narrow transosseous isthmus to an intraorbital component.
  - An orbital dermoid cyst slowly enlarges; it may internally rupture and produce intense regional inflammation after minor local trauma.
  - Surgical removal is indicated after CT scan to rule out intraorbital portion.
- Ptosis
  - Ptosis is eyelid droop that is usually unilateral. Urgent treatment is needed if the visual axis is obscured. Less urgent correction is indicated for astigmatism caused by the weight of the ptotic lid on the cornea or by an exaggerated

compensatory chin-up head position (when children maintain a chin-up position, they are attempting to use the ptotic eye; when the lid droop is such that the child is not even trying to use the ptotic eye, the visual axis is usually blocked in that eye by the lid).
  - The most common form of ptosis includes poor levator muscle function (upper lid movement is limited), manifested by reversal of ptosis on down-gaze.
    - The levator muscle is very inelastic, much like a leather belt. Treat with a frontalis sling.
    - If levator function is adequate (ie, upper lid has good movement), treat with levator resection.
  - Prominent epicanthal folds (skin fold over medial canthus gives the illusion of small-angle esotropia or crossed eyes) are a normal variant and no treatment is needed.
- Blepharitis (erythema of the lid margin)
  - Patient may have recurrent chalazia, lash loss, and scaling skin debris.
  - Blepharitis is common in those with trisomy 21.
  - It may be a sign of immunologic deficiency in severe or chronic cases.
  - It can be treated with proper lid hygiene and a mild topical antibiotic ointment before sleep.
- Nasolacrimal duct obstruction
  - Nasolacrimal duct obstructions are common in neonates and infants.
  - They are usually unilateral and manifest as chronic mucopurulent discharge with excess tearing (epiphora).
  - A nasolacrimal duct obstruction may be mistaken for chronic or recurrent conjunctivitis.
  - The discharge is often improved while the patient is using antibiotic drops or ointment, only to recur when the medication is discontinued. Antibiotics alone should have no effect on the excessive tearing.
  - Most cases resolve by 1 year of age.
  - Massaging the nasolacrimal sac may assist resolution.
  - Nasolacrimal duct probing and irrigation are indicated for those cases persisting at 1 year old; if probing fails to resolve symptoms, temporary silicone-tube stinting may be required (Figure 14-1).

a



b



Figure 14-1. **(a)**"00" Bowman probe introduction into right superior puncta and canuliculus. **(b)** Medial and superior rotation of probe, then inferior advancement of probe to hard palate. (**Figure 14-1** ***continues***)

c



d



Figure 14-1 ***continued***. **(c)** Replacement of probe with a long, 23-gauge, blunt-tip canula, then, irrigation of a very small amount (< 1 cc or mL) of fluorescein-stained normal saline. **(d)** Recovery of fluorescein from ipsilateral nares with 8 Fr suction catheter confirms open nasolacrimal duct. Avoid airway compromise from excessive irrigation.

- Conjunctivitis
  - Conjunctivitis is usually viral and self-limited.
  - Acute purulent conjunctivitis is usually bacterial and is characterized by hyperemia, edema, mucopurulent exudates, and ocular discomfort.
  - The most frequent organisms to blame are staphylococci, pneumococci, *Haemophilus influenzae*, and streptococci. Gram stain and culture are used to identify the specific organism, and infections usually respond to warm compresses and frequent instillation of topical antibiotic drops.
  - Viral conjunctivitis is usually associated with adenovirus and manifested by a watery (as opposed to purulent) discharge. This type is usually self-limited, Gram stain and bacterial cultures are negative, and treatment with topical sulfonamides is sufficient.
  - Chemical conjunctivitis may occur after prophylactic instillation of silver nitrate (1%), erythromycin ophthalmic ointment (0.5%), or azithromycin ophthalmic solution (1%) 12 to 24 hours after birth. No pathogens are identified and no treatment is necessary.
  - Most cases are treated by the patient's primary physician, but severe, chronic, recurrent, or unusual cases are often referred to an ophthalmologist.
  - Treat raised umbilicated lid lesions (molluscum contagiosum) by incision and curettage or simple scraping.
  - Conjunctivitis can be recurrent and associated with epiphora; if it always occurs on the same side, suspect nasolacrimal duct obstruction and arrange for probing and irrigation.
  - If probing fails to give long-term symptom relief, the patient may need a stent.
  - Epidemic keratoconjunctivitis manifests as small, scattered, superficial corneal infiltrates that are self-limited (may take 6–10 weeks to resolve). Treat with supportive care and mild topical antibiotic ointment before sleep to prevent bacterial superinfection.
- Ophthalmia neonatorum (Figure 14-2) is caused by infection due to *Neisseria gonorrhoeae* or *Chlamydia trachomatis* acquired by passage through the infected genital tract.



Figure 14-2. This was a newborn with *gonococcal ophthalmia neonatorum* caused by a maternally transmitted gonococcal infection. Unless preventative measures are taken, it is estimated that gonococcal ophthalmia neonatorum will develop in 28% of infants born to women with gonorrhea. It affects the corneal epithelium causing microbial keratitis, ulceration, and perforation. Reproduced from: Centers for Disease Control and Prevention Public Health Image Library Web site. Photograph courtesy of J Pledger. http://phil.cdc.gov. Accessed September 9, 2010. Image 3766.

  - Ophthalmia neonatorum results in profuse discharge, marked eyelid edema, and conjunctival hyperemia. If untreated, infection can lead to corneal perforation and blindness.
  - Gram stain demonstrates gram-negative diplococci in gonorrhea infections, and intracytoplasmic inclusion bodies in chlamydia. Both types of infections require systemic and topical antibiotics.
- Periorbital cellulitis refers to inflammation of the lids and periorbital tissues without involvement of the orbit itself.
  - It may be associated with trauma, wound, or abscess of the lid or periorbital region.
  - *Staphylococcus* and *Streptococcus* species are the most common organisms, and prompt treatment with systemic antibiotics is indicated to prevent development of an orbital abscess, cavernous sinus thrombosis, or meningitis.

- Anterior uveitis (iritis)
  - Anterior uveitis is uncommon in children; it usually follows blunt ocular trauma.
  - Symptoms may be photophobia and conjunctival injection (redness).
  - It is associated with juvenile idiopathic arthritis and may be painless in these patients; perform a baseline examination and periodic screening on all patients.
  - Treat with topical antiinflammatory steroids and a cycloplegic and mydriatic agent for patient comfort and to avoid synechiae of the iris to the cornea or lens; systemic immune suppressive agents may also be required.
  - Associated with sarcoidosis, especially in older children, children of African descent, and those with a positive family history.
  - Treat sarcoidosis with intensive topical antiinflammatory steroids, followed by a tapered dose.
  - Patients may require higher doses of oral steroids for a time; severe cases may require long-term topical or oral steroids to prevent rebound inflammation.
- Leukocoria (white pupil)
  - Retinoblastoma is a life-threatening malignancy that must be ruled out first in all leukocoria cases.
  - Leukocoria may be bilateral.
  - Leukocoria may be familial.
  - MRI scan and ultrasound are used most commonly to evaluate these tumors.
  - CT scan will show intralesional calcification, but is used less commonly now in an attempt to limit the child's exposure to radiation.
- A cataract is a lens opacity and is visually significant if the visual axis is blocked.
  - May be unilateral or bilateral; all bilateral cases require evaluation for infectious, genetic, and metabolic causes.
  - Congenital cataracts are present at birth; urgent removal is indicated. If left untreated by 6 to 8 weeks of age, irreversible nystagmus and amblyopia may occur. Congenital cataracts, especially in microphthalmic eyes, are highly associated with subsequent glaucoma.

  - Infantile cataracts are present within the first year of life; urgent removal is indicated, but there is a lower association with glaucoma.
  - Acquired cataracts may be associated with trauma, steroid use, or less common lens defects (posterior lentiglobus or lenticonus; Figure 14-3).
- Amblyopia management is required for many years after cataract removal (at least until age 8).
- Unilateral aphakia (absent lens) places the affected eye at a significant disadvantage to the "normal" eye, making amblyopia much more difficult to manage.
  - Patching the better eye for 2 to 6 hours a day forces vision development in the aphakic eye, and refractive treatment with a special aphakic contact lens or an intraocular lens is preferred over unilateral aphakic glasses for better binocularity development.
  - Bilateral aphakia makes amblyopia management less difficult. Aphakic contact lenses, aphakic glasses, or intraocular lenses may be used. Patching is only needed if a disparity in visual acuity is noted.
  - Following cataract removal, up to a third of all affected eyes may develop glaucoma by adulthood.



Figure 14-3. Acute traumatic cataract left eye.

  - Pediatric cataracts are best managed by those experienced in their evaluation and treatment.
- Toxocara granuloma (from dog hookworm larvae) is an ocular form of visceral larva migrans characterized by severe local granulomatous inflammation due to dead worm larvae.

Retinal Disorders

Retinopathy of Prematurity

- ROP is an abnormal blood vessel growth with a risk of tractional retinal detachment.
- It is associated with prematurity (< 30 weeks gestation) and birth weight less than 1,500 g.
- These patients are screened while in the neonatal intensive care unit and screening is continued until the retina is fully vascularized, the ROP resolves, or the treatment threshold is met.
- Treatment consists of laser photocoagulation of the peripheral avascular retina or intravitreal injection of bevacizumab (see Mintz-Hitner, et al, in Further Reading). Evaluation and treatment of ROP during the acute phases should be performed by ophthalmologists experienced in dealing with this condition. Bevacizumab may prove to be as efficacious, more readily available, and easier to administer than laser as the treatment of ROP, especially in a hostile environment.
- Long-term periodic follow up is required to screen for early onset myopia.

Nonaccidental Trauma

- Nonaccidental trauma, such as shaken baby or shaken impact syndrome, may cause multiple intraretinal and preretinal hemorrhages in the macula, extending to the mid-periphery due to disruption of venous outflow or peripheral hemorrhages at the vitreous base due to a shearing effect.
- When intraretinal hemorrhages are present, there is often also neurological depression, which may be life threatening.
- Screening examinations are usually requested by the pediatrics service associated with infants or toddlers presenting with injuries inconsistent with their history or with multiple injuries of various chronology.

- Social services and law enforcement officials are required to be notified in all suspected nonaccidental trauma cases. Photo documentation of the retinal findings is becoming the medical-legal standard for prosecuting the responsible individuals (though this is not usually available in a deployed environment).

Optic Nerve Abnormalities

- A large cup-to-disc ratio is an indicator of possible glaucoma in adults, but the majority of pediatric patients with large cup-to-disc ratios do not have glaucoma. Check the patient's IOP and central corneal thickness (pachymetry), then follow with baseline photos and ocular coherence tomography.
- Acute papilledema is a sign of increased intracranial pressure characterized by bilateral blurred disc margins, elevated discs, obscuration of vessels, and hemorrhages. It may indicate an intracranial tumor. An immediate imaging of the brain (CT or MRI) is indicated, and neurological or neurosurgical evaluation is required.
- Optic nerve coloboma (incomplete closure of embryologic fetal fissure) presents an increased lifetime risk of retinal detachment. Patients with this disorder may also have chorioretinal coloboma at the inferior nasal location. It may be associated with systemic abnormalities or syndromes and requires periodic observation and surgery for retinal detachment (as needed).

Refractive Error

- Treat a high refractive error (like one of the following) with eyeglasses to prevent or treat amblyopia.
  - Symmetric astigmatism greater than 3 diopters.
  - Myopia greater than 6 diopters.
  - Hyperopia greater than 6 diopters.
- Anisometropia greater than 1.50 diopters difference requires refractive treatment.
- Mild to moderate levels of myopia do not need treatment; however, school-aged children with this level of myopia will need to wear eyeglasses for good distance vision. Encourage children to remove their glasses for prolonged near tasks.

- Mild to moderate levels of hyperopia do not require treatment unless there is intermittent esotropia (see strabismus section below); however, school-aged children with moderate (greater than 3.00 diopters) hyperopia may need glasses for prolonged near work.
- Strabismus is defined as an eye misalignment of any type and is the most common reason for pediatric eye surgery.
  - Comitant strabismus is an ocular misalignment in which there is a similar quantitative deviation in all directions of gaze.
  - Congenital esotropia is the most common strabismus.
  - There is usually a large angle of deviation, but amblyopia is rare and often mild because of cross-fixation (spontaneous alternation of eyes). Treat with strabismus surgery (bilateral medial rectus recessions) around 5 to 7 months of age, if possible.
- Accommodative esotropia is associated with high hyperopia, especially when actively focusing on an object (distant or near) or when fatigued. Onset is around 18 months to 4 years of age and is usually initially intermittent. The child may have greater esodeviation on near sight and a high ratio of accommodative convergence to accommodation (AC/A).
- The patient may develop amblyopia quickly in the nondominant (esodeviating) eye. Treat with "plus power" eyeglasses; give the full cycloplegic refraction.
- Patients with a high ratio of AC/A may require bifocals. The bifocal segment must be 1 mm below the visual axis (at the level of the pupil). Surgery is reserved for patients with residual esodeviations while in full cycloplegic refraction.
- Use bilateral medial rectus recessions with or without posterior fixation sutures (preferred), or on eyes with refractory amblyopia, a unilateral medial rectus recession and lateral rectus resection (recess-resect procedure) may be considered.
- Intermittent exotropia often manifests when an individual is visually inattentive, fatigued, ill, or has taken medications that decrease alertness.
- There is a highly variable age of onset.

- Individuals typically have excellent control of ocular alignment at near distances (divergence excess pattern), only exhibiting a well-controlled exophoria with near fixation, which permits the development of good binocularity.
- Vision is usually normal in each eye.
- Stereopsis is usually normal.
- Up to a third of patients may improve with accommodative exercises; daily alternate-eye patching may improve some cases.
- Patients not responding to the above measures may be treated with strabismus surgery (bilateral lateral rectus recessions).
- Consecutive strabismus is a deviation that occurs months to years after strabismus surgery, usually in the opposite direction of the initial surgery (typically exotropia after surgery for esotropia). Treat with either bilateral recessions of the lateral rectus muscles (for exotropia or a lateral rectus weakening [recession]/medical rectus strengthening [advancement/resection] procedure on the nondominant eye if the near deviation approximates or exceeds the distance deviation due to the previously recessed medial rectus muscles). Medial rectus muscle recessions typically work well for consecutive esotropia.
- Noncomitant strabismus is a condition in which ocular misalignment varies according to the direction of the patient's gaze.
  - Superior oblique, or trochlear, palsy (cranial nerve IV palsy) usually presents with a head tilt away from the affected side.
  - Longstanding cases often present with intermittent diplopia (rare in children). The patient may have facial asymmetry with contralateral facial hypoplasia (hemifacial microsomia).
- Treat with strabismus surgery. The most common procedure is to weaken the ipsilateral inferior oblique muscle either by recession or myectomy. The next most common is a tuck (shortening) of the affected superior oblique tendon.
- Other conditions associated with strabismus include
  - Duane syndrome.
  - Brown syndrome.
  - Monocular elevation deficiency (double elevator palsy).

Ocular Manifestations of Systemic Disease

- Aniridia: Wilms tumor.
- Blue sclera: osteogenesis imperfecta.
- Kayser-Fleischer corneal ring: Wilson disease.
- Congenital cataracts: intrauterine infection.
- Leukocoria (white reflex in the pupil): retinoblastoma.
- Retinal hemorrhages with white centers (Roth spots): subacute bacterial endocarditis.
- Chorioretinitis: toxoplasmosis, histoplasmosis, cytomegalovirus, tuberculosis, syphilis.

Pediatric Eye Injuries

General Guidance

The examiner must have a high index of suspicion; patients may not self-report because they are too young, fear reprisal for having participated in unapproved behavior that resulted in the accidental injury, or are victims of nonaccidental trauma. These injuries are not frequently witnessed or reported by adults and may only be suspected after a delayed presentation for medical evaluation.

- Physical symptoms include
  - reluctance to open an eye,
  - reported or observed redness of an eye,
  - photophobia,
  - excessive tear production, and
  - pain.
- Vision examination
  - Carefully measure vision (eg, patient's reaction to light, distance at which patient can count fingers, etc).
  - Use any printed material (books, medication labels, etc) if a vision-screening card is not available.
  - Compare sight in the injured eye to that in the uninjured eye.
  - Severe vision loss is a strong indicator of serious injury.
  - If there is a lid laceration, suspect and carefully check for signs of possible underlying globe laceration; examine the eyes prior to lid repair. Be sure to evaluate and repair the canalicular (tear duct) system.

Ruptures and Lacerations (Open Globe)

These injuries may result from penetrating or blunt eye trauma and may cause vision loss from either disruption of ocular structures or secondary infection (endophthalmitis).

- Signs include
  - Hemorrhagic chemosis (elevation of the conjunctiva from the sclera by dense bleeding).
  - Hyphema (blood in the anterior chamber); if rupture is complete, an "eight ball" hyphema is present (may also be present in severe blunt trauma).
  - Disrupted anterior chamber architecture.
  - Irregular or teardrop pupil shape (peaked pupil).
  - Dark iris or uveal tissue protruding through cornea.
- If there are signs of fragmentation injury (by either primary or secondary missiles) to the head, neck, or face, intraocular foreign bodies may be present.
- Proptosis may indicate a retrobulbar hemorrhage; urgent lateral canthotomy and cantholysis may be indicated.
- Decreased motility of one eye may be a sign of an open globe. Other causes of limited motility include muscle injury, orbital fracture, and orbital hemorrhage.
- Treating an open globe injury
  - In a casualty with severe vision loss, a traumatic hyphema, a large subconjunctival hemorrhage, or other signs of an open globe injury with an intraocular foreign body, biplanar radiographs or a CT scan of the orbit may initially help identify a metallic intraocular fragment.
  - Immediate treatment of an open globe injury is as follows.
    - Tape a rigid eye shield (not a pressure patch) over the eye. Gauze or an eye patch under the shield may adhere to the underlying exposed tissues and, when removed, could actually worsen the injury.
    - Do not apply pressure to or manipulate the eye (ie, no ultrasound).
    - Do not apply topical medications.
    - Start a quinolone antibiotic (oral or intravenous [IV]; dose for patient weight).
    - Schedule an urgent (within 12–24 h) referral to an ophthalmologist.

- Administer tetanus toxoid, if indicated.
- Use antiemetics (dose for patient weight).
- The patient can expect surgical exploration and globe repair under general anesthesia by the initial ophthalmologist; further procedures may be required later.

Subconjunctival Hemorrhage

- Small subconjunctival hemorrhages (SCHs) may occur spontaneously or in association with blunt trauma; these lesions require no treatment and resolve in days to weeks.
- SCH may also occur in association with a rupture of the underlying sclera.
- Warning signs for an open globe include a large SCH with chemosis (conjunctiva bulging away from globe) in the setting of blunt trauma, or any SCH in the setting of penetrating injury. Casualties with blast injury and normal vision do not require special immediate ophthalmologic care, but should get a complete ophthalmic examination at the earliest opportunity. Suspected open globe patients should be treated as described above (see Ruptures and Lacerations).

Chemical Injuries of the Cornea

- Initiate immediate copious irrigation (maintain for 30 min) with normal saline, lactated Ringer's, or balanced salt solution (nonsterile water may be used if it is the only liquid available). A Morgan lens is often used to facilitate irrigation. Use a topical anesthetic prior to initiating irrigation.
- Measure tear pH to ensure that irrigation continues until the pH returns to normal (7.35–7.45); do not use alkaline solutions to neutralize acidity (or vice versa).
- Remove any retained particles.
- Use fluorescein strips or drops with a Wood's lamp or other source of cobalt blue light and examine for epithelial defects.
  - If none are found, treat mild chemical injuries or foreign bodies with artificial tears.
  - If an epithelial defect is present, use a broad-spectrum antibiotic ophthalmic ointment (bacitracin/polymyxin, erythromycin, or bacitracin) 3 to 4 times per day (same dosing as for adults).

  - Apply a pressure patch between drops of ointment if there is a large epithelial defect.
  - Monitor (via daily topical fluorescein evaluation) for a corneal epithelial defect until epithelial healing is complete (as determined by a negative fluorescein evaluation).
- Noncaustic chemical injuries usually resolve without sequelae.
- Severe acid or alkali injuries of the eye (recognized by pronounced chemosis, limbal blanching, or corneal opacification) can lead to infection of the cornea, glaucoma, and possible loss of the eye.
  - Refer the patient to an ophthalmologist within 24 to 48 hours.
  - These more severe chemical injuries may also require treatment with prednisolone 1% drops 4 to 9 times per day, and scopolamine 0.25% drops 2 to 4 times per day (these should only be started on the direction of an ophthalmologist).

Corneal Abrasions

- Be alert for the possibility of an associated open globe injury.
- The eye is usually symptomatic, with pain, tearing, and photophobia; vision may be diminished from the abrasion itself or from profuse tearing.
- Diagnose with topical fluorescein and cobalt blue light or Wood's lamp (if available).
- A topical anesthetic may be used for diagnosis, but should not be used as an ongoing analgesic agent (this delays healing and may cause other severe complications).
- Apply broad-spectrum antibiotic ointment (polymyxin B, erythromycin, or bacitracin) four times a day.
- Pain relief options include
  - a pressure patch or a bandage soft contact lens (usually sufficient for most abrasions);
  - diclofenac 0.1% drops, four times a day; and
  - a short-acting cycloplegic agent (1% tropicamide or 1% cyclopentolate) and a pressure patch for larger abrasions.
- More severe discomfort can be treated with 0.25% scopolamine (1 drop twice a day), but this will result in pupil dilation and blurred vision for 5 to 6 days.

- Small abrasions usually heal well in 1 to 4 days without patching; if the eye is not patched, antibiotic drops (fluoroquinolone or aminoglycoside) may be used four times a day in lieu of ointment. Sunglasses are helpful in reducing photophobia.
- All corneal abrasions need to be checked once a day until healing is complete to ensure the abrasion has not been complicated by secondary infection (eg, corneal ulcer, bacterial keratitis).
- Thermal burns of the cornea are initially treated in the same manner as corneal abrasions.
- Laser-induced injuries usually involve the retina, which is the most vulnerable tissue. Degree of injury depends on the duration of exposure and amount of energy delivered. A reduction in visual acuity, tearing, and pain are the main symptoms of laser injury.
- Nonpenetrating corneal injuries (anterior segment) should be treated the same way as corneal abrasions. Injury involving the posterior segment should be referred to an ophthalmologist as soon as possible.

Corneal Ulcer and Bacterial Keratitis

- Corneal ulcer and bacterial keratitis are serious conditions that may cause vision or eye loss.
- These conditions are associated with soft contact lens wear, especially if contacts are not taken out prior to sleep.
- Symptoms include increasing pain and redness, decreasing vision, persistent or increasing epithelial defect (positive fluorescein test), and a white or gray spot on the cornea (seen on examination with penlight or direct ophthalmoscope).
- Treatment includes quinolone drops (1 drop every 5 min for 5 doses initially, then 1 drop every 30 min for 6 h, then 1 drop hourly thereafter).
  - Scopolamine 0.25% (1 drop twice daily) may help relieve discomfort caused by pupillary spasm; patching and use of topical anesthetics for pain control are contraindicated.
  - Expedite referral to an ophthalmologist (within 1–2 days).

Conjunctival and Corneal Foreign Bodies

- These present with abrupt onset of discomfort or history of suspected foreign body.
- If an open globe injury is suspected, treat as discussed in Ruptures and Lacerations.
- Definitive diagnosis requires visualization of the offending object, which may be difficult; a hand-held magnifying lens or pair of reading glasses will help.
  - Stain the eye with fluorescein to check for a corneal abrasion.
  - The patient may be able to indicate the perceived location of the foreign body prior to instillation of topical anesthesia.
  - Eyelid eversion with a cotton-tipped applicator helps the examiner identify foreign bodies located on the upper tarsal plate.
- Treatment
  - Superficial conjunctival or corneal foreign bodies may be irrigated away or removed with a moistened sterile swab under topical anesthesia.
  - Objects adhering to the cornea may be removed with a spud or the edge of a sterile 22-gauge (or larger) hypodermic needle mounted on a tuberculin syringe (hold the needle tangential to the eye to avoid iatrogenic ocular penetration and corneal perforation).
  - If no foreign body is visualized but the index of suspicion is high, the foreign body may be removed by vigorous irrigation with artificial tears or sweeps of the conjunctival fornices with a moistened, cotton-tipped applicator (after applying topical anesthesia).
  - If an epithelial defect is present after the foreign body is removed, treat as a corneal abrasion (see Corneal Abrasions section).

Hyphema (Blood in the Anterior Chamber)

- Treat to prevent permanent vision loss from increased IOP or corneal blood staining.
- Suspect associated significant intraocular damage (at the site of the hemorrhage).

- Suspect a possible open globe and treat appropriately.
- A major goal of management is to avoid rebleeding.
  - Avoid aspirin and nonsteroidal antiinflammatory drugs.
  - Limit activity (require bed rest, with the patient only getting up to use the bathroom) for 7 to 10 days.
  - Administer prednisolone 1% drops four times a day, and scopolamine 0.25% drops twice daily.
  - Cover the eye with a protective shield.
  - Elevate the head of the bed to promote settling of red blood cells in the anterior chamber (Figure 14-4).
  - Patient should be seen by an ophthalmologist within 24 to 48 hours to monitor for increased IOP (which may cause permanent injury to the optic nerve or corneal

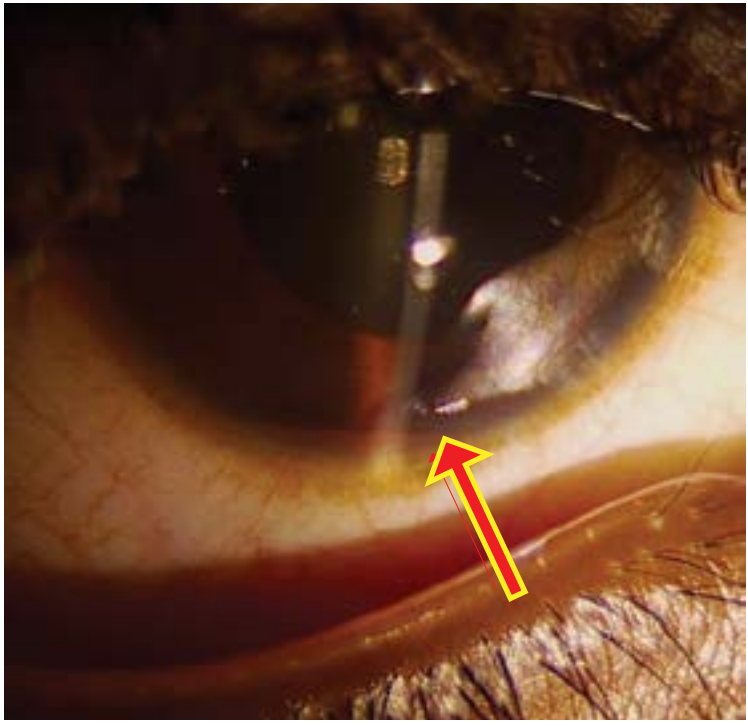


Figure 14-4. Blood aqueous level (arrow) indicates 5% hyphema.

blood-staining and secondary deprivation amblyopia) and to evaluate for associated eye injuries.

- If evaluation by an ophthalmologist is delayed (longer than 24 h), treat with a prostaglandin analogue, such as latanoprost once daily at bedtime, or a topical β-blocker (timolol or levobunolol) twice daily to help prevent IOP elevation.
- If IOP is found to be markedly elevated (above 30 mmHg) with a portable tonometry device, other options for lowering it include administering acetazolamide (oral or IV) or mannitol (IV), dosed for the patient's weight.

Retrobulbar (Orbital) Hemorrhage

- Symptoms include severe eye pain, proptosis, vision loss, and decreased eye movement.
- Marked lid edema may make the proptosis difficult to recognize; however, failure to recognize may result in blindness from increased ocular pressure.
- Treatment
  - Perform an immediate lateral canthotomy and inferior cantholysis (see below for detailed instructions).
  - Provide an urgent referral to an ophthalmologist (within 6 to 12 h).
  - If evaluation by an ophthalmologist is delayed (more than 24 h), treat with a topical β-blocker (timolol) twice a day to help lower IOP elevation.
  - If IOP is found to be elevated (greater than 30 mmHg), follow the first two steps.
  - Perform lateral canthotomy and cantholysis.
    - Do not perform these procedures if the eyeball structure has been violated; if the globe is open, apply a Fox shield (Bausch & Lomb, Bridgewater, New Jersey) for protection and seek immediate ophthalmic surgical support.
    - Inject 2% lidocaine with 1:100,000 epinephrine into the lateral canthus to the rim.
    - Crush the lateral canthus with a straight hemostat, advancing the jaws to the lateral fornix/orbital rim.

- Using straight scissors, make a 1-cm long horizontal incision of the lateral canthal tendon, in the middle of the crush mark to the rim.
- Grasp the lower eyelid with large, toothed forceps, pulling the eyelid away from the face; this pulls the inferior crus (band of the lateral canthal tendon) tight so it can be easily cut loose from the orbital rim.
- Use blunt-tipped scissors to cut the inferior crus; keep the scissors parallel (flat) to the face with the tips pointing toward the chin.
- Place the inner blade just anterior to the conjunctiva, and the outer blade just deep to the skin; the eyelid should pull freely away from the face, releasing pressure on the globe.
- Cut residual lateral attachments of the lower eyelid if it does not move freely. Keep in mind that this procedure is performed to urgently alleviate dangerously high retrobulbar pressure; in this situation, cosmesis is irrelevant. Make generous cuts, at least 1 cm vertical and 1 cm horizontal. The lid defect can be repaired once the emergency has been addressed.
- If the intact cornea is exposed once the lower eyelid is cut and orbital pressure is relieved, apply copious erythromycin ophthalmic ointment or ophthalmic lubricant ointment hourly to prevent devastating corneal desiccation and infection. Orbital pressure relief must be followed by lubricating protection of the cornea and urgent ophthalmic surgical support. Do not apply absorbent gauze dressings to the exposed cornea.

Orbital Floor (Blowout) Fractures

- These fractures are usually the result of a blunt injury to the globe or orbital rim and may be associated with head and spine injuries.
- Blowout fractures may be suspected on the basis of enophthalmos, diplopia, decreased ocular motility, hypoesthesia of the V2 branch of the trigeminal nerve, associated subconjunctival hemorrhage, or hyphema.

- Immediate treatment includes administering broad-spectrum antibiotics for 7 days, applying ice packs, and instructing the casualty to avoid nose blowing.
- Definitive diagnosis requires a CT scan of the orbits with axial and coronal views.
- Indications for repair include severe enophthalmos and diplopia in the primary or reading-gaze positions. The surgery may be performed 1 to 2 weeks after the injury, but may have greater success in children if it is performed as soon as possible in trapdoor-style blowout fractures.
- Patients with an orbital floor (blowout) fracture often have a limited (restricted) upgaze on the affected side and may also have a restricted downgaze on the affected side. Early surgical intervention may be indicated, especially if there is a trapdoor fracture that results in entrapment of the inferior rectus on the affected side. In this circumstance, attempted upgaze may stimulate the oculocardiac reflex, which is associated with nausea, vomiting, and severe bradycardia, even to the point of asystole.
- Strabismus surgery is reserved for patients with diplopia in the primary gaze (straight ahead) or in the reading position (moderate downgaze).

Lid Lacerations

- Treatment for lid lacerations not involving the lid margin is as follows.
  - Delayed primary closure is not necessary when there is adequate blood supply.
  - Eyelid function (protecting the globe) is the primary consideration.
  - Begin with irrigation and antisepsis (using any topical solution), and check for retained foreign bodies.
  - Superficial lacerations of the eyelid that do not involve the eyelid margin may be closed with running or interrupted polypropylene (preferred for adults), 6-0 silk, or nylon sutures. For children, consider absorbable sutures such as gut, fast gut, or chromic sutures.
  - Horizontal lacerations should include the orbicularis muscle and skin in the repair.

- If skin is missing, an advancement flap may be created to fill in the defect. For vertical or stellate lacerations, use traction sutures in the eyelid margin for 7 to 10 days.
- Apply antibiotic ointments four times a day until sutures are removed. Skin sutures may be removed in 5 days.

- Treatment guidelines for lid lacerations involving the lid margin are as follows.
  - Tissue loss greater than 25% will require a flap or graft (less in children with little, if any, lid laxity).
  - When repairing a marginal lower-eyelid laceration with less than 25% tissue loss, the irregular laceration edges may be freshened by creating a pentagonal wedge. Remove as little tissue as possible.
  - Place a 5-0 or 6-0 silk or nylon suture in the eyelid margin (through the grayline, 2 mm from the wound edges and 2 mm deep) and tie it in a slipknot; symmetric suture placement is critical to obtaining postoperative eyelid margin alignment.
  - Loosen the slipknot and place two or three absorbable 5-0 or 6-0 sutures (Vicryl [Ethicon, Somerville, New Jersey], not gut or chromic) internally to approximate the tarsal plate; the skin and conjunctiva should not be included in this internal closure.
  - Place anterior and posterior marginal sutures (6-0 silk) in the eyelid margin just in front of and behind the previously placed suture.
  - Leave all suture tails long and drape them over the lid margin onto the skin surface. Tape them or incorporate them into the skin sutures to prevent them from abrading the cornea.
  - Close the skin with Prolene (Ethicon, Somerville, New Jersey), 6-0 silk, gut, or nylon sutures and place the lid on traction for at least 5 days.
  - Remove the skin sutures at 3 to 5 days, and the marginal sutures at 10 to 14 days.
  - If there is orbital fat in the wound or if ptosis is noted in an upper lid laceration, damage to the orbital septum and the levator aponeurosis should be suspected. Do not suture; immediately refer to an ophthalmologist.

  - If the eyelid is avulsed, the missing tissue should be retrieved, wrapped in a moistened, nonadherent dressing, and preserved on ice. The tissue should be soaked in a dilute antibiotic solution prior to reattachment. Avoid debridement of the lid, which is very resilient. Lid lacerations often appear worse than they actually are. Injured orbicularis often retracts, making gaps appear larger. Attempt to reapproximate the tissue with forceps and likely most (if not all) of the tissue will be found. Any avulsed tissue should be secured in the anatomically correct position in the manner described for lid margin repair. Lubricate, shield the eye, and promptly refer the patient to an ophthalmologist or plastic surgeon.
- Damage to the canalicular system can occur as a result of injuries to the medial aspect of the lid margins.
  - Suspected canalicular injuries should be repaired by an ophthalmologist with monocanalicular (if available) or bicanalicular intubation to prevent subsequent problems with tear drainage. The tubes should remain in place for 3 to 6 months.
  - This repair can be delayed for up to 24 hours.

Enucleation

- Whenever possible, an ophthalmologist should perform an enucleation; however, a general surgeon in a forward unit could remove a traumatized globe if it is completely disorganized.
- Enucleation should only be considered if the patient has a very severe injury, exhibits no light perception when the provider uses the brightest light source available, and is not able to be evacuated to a facility with an ophthalmologist.
- Sympathetic ophthalmia is a condition that may result in loss of vision in the uninjured eye if a severely traumatized, blind eye is not removed, but it rarely develops prior to 14 days after an injury; thus, delaying the enucleation until the patient can see an ophthalmologist is relatively safe and advisable.

Further Reading

1. Mintz-Hittner HA, Kennedy KA, Chuang AZ, et al. Efficacy of intravitreal bevacizumab for stage 3+ retinopathy of prematurity. *N Eng J Med*. 2011;364:603–615.

Chapter 15

Pediatric Dental Surgery

Introduction

Pediatric dentistry is defined as the diagnosis and treatment of oral disease in children from birth to age 18, and includes care of developmentally disabled patients. Dental disease (caries) is the most common infectious disease in children.

Primary teeth erupt at 4 to 30 months, sequentially from mandibular dentition to maxillary. Twenty primary teeth (10 per arch) erupt with normal spacing. Children should have their first dental visit by 6 months of age.

Of the secondary teeth, permanent molars and mandibular incisors erupt first, by 6 years of age. The remainder erupt by 18 years of age, third molars included, for a total of 32 total permanent teeth. It is not uncommon for permanent mandibular incisors to erupt behind primary incisors.

Dental Caries

- Dental caries is caused by infectious disease; *Streptococcus mutans* is the most common cause. It may also be caused by parental microbe transmission.
- Carbohydrate, tooth surface, and microorganisms are required for caries to develop.
- Dental caries may be mild or severe.
- Complications include pain, inability to chew, facial abscess, and facial swelling.
- Treatment includes restorative dentistry and root canal or extraction of the offending tooth.

Preventing Tooth Decay

- Decrease refined sugar intake.

- Do not let children use a bottle at night with sweetened fluids.
- Provide fluoride supplementation.
- Avoid bottle propping.

Toothache

- Emergency treatment may be needed for toothache, especially when decay is visible.
- Gently debride visible decay.
- Apply immediate restorative material into the cavity (contains eugenol to eliminate pain; Figure 15-1).
- Local anesthetics that temporarily relieve toothache and extraction pain include
  - 1% or 2% lidocaine with or without epinephrine 1:100,000 (use a 3-cc syringe, 22-gauge 1½-inch needle).
  - 0.5% bupivacaine for long-acting local anesthesia.
  - maximum 1% or 2% lidocaine with or without epinephrine (2 mg/pound [4.4 mg/kg] bupivacaine [1.3 mg/kg], per American Academy of Pediatric Dentistry guidelines).



Figure 15-1. Immediate restorative material for temporary pain relief.



Figure 15-2. Inferior alveolar nerve block.

- Techniques for pain relief include
  - Inferior alveolar nerve block (Figure 15-2).
  - Local infiltration (Figure 15-3).
  - Periodontal ligament injection.



Figure 15-3. Local infiltration anesthesia.

- Always aspirate before injecting local anesthetics. Lip and tongue trauma are common during the anesthetic period following an inferior alveolar nerve block.

Extraction

- Extraction is indicated in cases of severe tooth pain, abscesses, severe gum (periodontal) disease, and traumatic injuries.
- Tooth root structure
  - Anterior teeth have single roots.
  - In most instances, molars have three roots.
  - Bicuspids (premolar) have one or two roots.

Equipment

- Maxillary and mandibular forceps for both maxillary and mandibular incisors and posterior teeth (Figure 15-4).
- Elevator to loosen teeth before extraction (Figure 15-5).
- Needle holder, #15 scalpel, 4-0 chromic suture material (Figure 15-6).



Figure 15-4. Forceps for extraction of maxillary and mandibular dentition.



Figure 15-5. 301 elevator.

Technique

- If possible, take a radiograph to look for multiple roots and root fracture.
- Inject sufficient local anesthetic.
- Loosen the selected tooth using a 301 elevator (see Figure 15-5).
- Firmly grasp the tooth with a forceps. Manipulate the tooth from front to back until the periodontal ligament breaks.
  - For anterior teeth: use a rotational motion to extract the tooth.



Figure 15-6. Needle holder, suture, and #15 scalpel.

- For posterior teeth: grasp firmly and use facial direction to extract molars (Figure 15-7). If the root is fractured and cannot be easily removed, it should be left in place.

Oral Pathology

Dentoalveolar Abscesses

- Dentoalveolar abscesses may be localized or involve facial spaces.
- Definitive treatment consists of extracting the offending tooth. If the tooth cannot be removed and intraoral swelling is present, use an 18-gauge needle and 5-cc syringe to aspirate purulent material, or incise and drain carefully with #15 scalpel.
- Antiinfective agents should be used for mild to moderate infections.
  - Prescribe oral clindamycin (10 mg/kg/day) every 6 hours for 7 days.

  - Prescribe oral amoxicillin (50 mg/kg/day) every 6 hours for 7 days.
- For severe infections, give clindamycin (20 mg/kg/day) IV every 6 hours for 7 days. Hospitalization is indicated for
  - severe trismus,
  - dehydration,
  - swelling beneath the mandible,
  - inability to protrude the tongue, and
  - orbital swelling.
- Mucocele is caused by an obstruction of a salivary gland and is commonly located on the mucosal surface of the lower lip. Treat by removing the minor salivary gland.

Eruption Hematoma

- An eruption hematoma is a blood-filled area near an erupting tooth.
- Bluish-red in color.
- There is no treatment for an eruption hematoma.

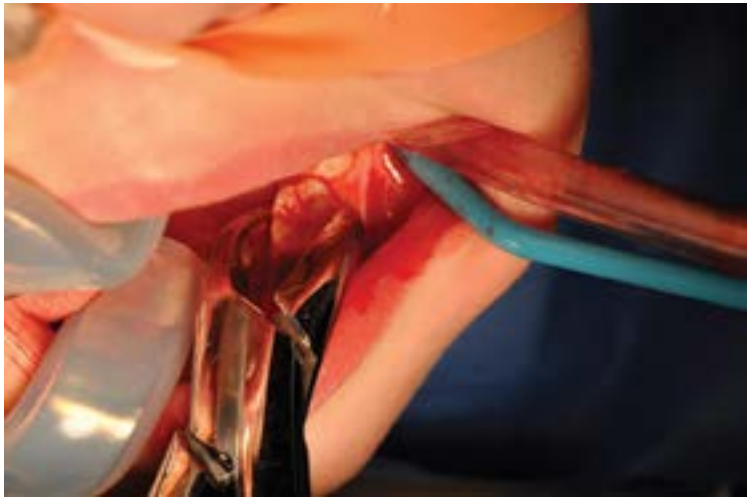


Figure 15-7. Extraction of posterior molar.

Natal and Neonatal Teeth

- Natal and neonatal teeth are teeth that are present at birth (natal) or within 30 days after birth (neonatal).
- They are usually mandibular incisors.
- No treatment is needed unless the tooth is very mobile or causes pain for the mother while breast-feeding.

Pyogenic Granuloma

- A pyogenic granuloma is a localized mass, sometimes on gingiva, associated with traumatic irritation from calculus deposits.
- These disappear with removal of the cause.

Aphthous Ulcers

- Aphthous ulcers are painful oral lesions located on unattached oral mucosa (Figure 15-8).
- They appear as a red halo with a pale center.
- Causes include allergies, immunological factors, and infection with L-form Streptococci.



Figure 15-8. Aphthous ulcer.

- Aphthous ulcers usually disappear after 10 to 14 days without treatment. Pain can be treated with
  - an oral paste containing benzocaine used twice daily,
  - chlorhexidine gluconate 0.12% oral mouth rinse used twice daily, or
  - amoxicillin for very large, painful lesions (50 mg/kg/day for 10 days).

Riga-Fede Disease

- Riga-Fede disease appears as irritation from the incisor to the lingual portion of tongue with ulceration.
- Treat by extracting the tooth or smooth the edges of the offending tooth.

Herpetic Gingivostomatitis

- Herpetic gingivostomatitis is caused by herpes simplex virus. It may be primary or recurrent.
- Primary herpetic gingivostomatitis is very painful and manifests as crops of vesicles located on the lips, gingiva, and palate.
  - The patient may become dehydrated from decreased fluid intake.
  - Infection may be severe.
  - Infants usually require hospitalization and intravenous fluids.
- Treatment consists of acyclovir for severe infections and hydration (oral or intravenous).
- The virus can be transmitted to the digits and eyes.

Dentoalveolar Trauma

- Causes of dentoalveolar trauma include falls, motor vehicle accidents, and altercations. Careful neurological examination should be performed when assessing trauma to the head or facial region.
- Check the patient's tetanus immunization status and administer toxoid or immunoglobulin, as appropriate.
- Assess pupillary size and reactivity and assign a Glasgow Coma Scale score as part of the neurological examination.



Figure 15-9. Severely displaced maxillary incisors.

- Always consider non-accidental injury as a possible etiology.
- Fractured teeth are classified (Ellis classifications) and treated as follows.
  - I: enamel fracture only; smooth area with file.
  - II: enamel/dentin; bonding agents and restoration.
  - III: pulpal exposure; pulpal protection and restoration, root canal therapy.

Avulsion of Teeth

- In the case of primary teeth, do not reimplant.
- For permanent teeth, reimplantation done within 2 hours of the incident results in the best chance of success (Figure 15-9).
- Reimplantation technique
  - Do not scrub the tooth.
  - Store the tooth in milk or a balanced salt solution.



Figure 15-10. Repositioned maxillary incisors (always check occlusion with mandibular teeth).



Figure 15-11. Splint made of flexible orthodontic wire (0.018 inch) bonded with composite.

- Take a radiograph of the area if the tooth is fractured (soft tissue).
- Reimplant the tooth (Figure 15-10).
- Stabilize the implanted tooth with 0.018 stainless steel wire for 1 week (Figures 15-11 and 15-12).
- Root canal therapy may be required.
- Antibiotics may be needed (eg, amoxicillin, clindamycin) if the area is grossly contaminated or infected.

Intrusion of Teeth

- For primary teeth, obtain a radiograph to ascertain whether or not the root is fractured. The tooth may re-erupt.
- For permanent teeth, obtain a radiograph of the area. Orthodontic extrusion is needed in many cases.



Figure 15-12. Maxillary incisors after splint removal.

Luxation of Anterior Teeth

- If the tooth is very mobile, remove it.
- A radiograph is needed to ascertain whether the root is fractured.
- Manually realign the tooth within the arch.
- The tooth may need stabilization with 0.018 stainless steel wire and enamel bonding agents.
- Follow-up is needed for possible pulpal therapy.

Chapter 16

Face and Neck

Ear, nose, and throat (ENT) disorders are very common in children in the developing world. Providing care for even common ENT problems (tonsillectomy, pressure equalizer tubes, etc) in austere or hostile environments may be associated with many complications.

General Principles of Pediatric Ear, Nose, and Throat Care in Hostile Environments

Generally, avoid procedures for which adequate follow-up care is unavailable, take into account the entire post-procedure recovery period (including the time after discharge from the hospital), and do not compromise the standard of care in austere environments. Consider the relationship of the patient to the person who is providing consent, the consenting individual's ability to understand the procedure, and outcomes and care requirements.

Disorders of the Upper Airway

Choanal Atresia

Choanal atresia is a congenital obstruction of the posterior nasal choana (Figure 16-1). The obstruction may be bony, membranous, or mixed.

- Unilateral choanal atresia presents with mild respiratory symptoms and rhinorrhea.
- Bilateral choanal atresia manifests as intermittent respiratory distress in infants (cyclical cyanosis: breathing when crying, cyanosis when quiet. Infants are obligate nasal breathers).
- Diagnosis is made when a nasal catheter cannot be passed into the pharynx, with imaging (computed tomography

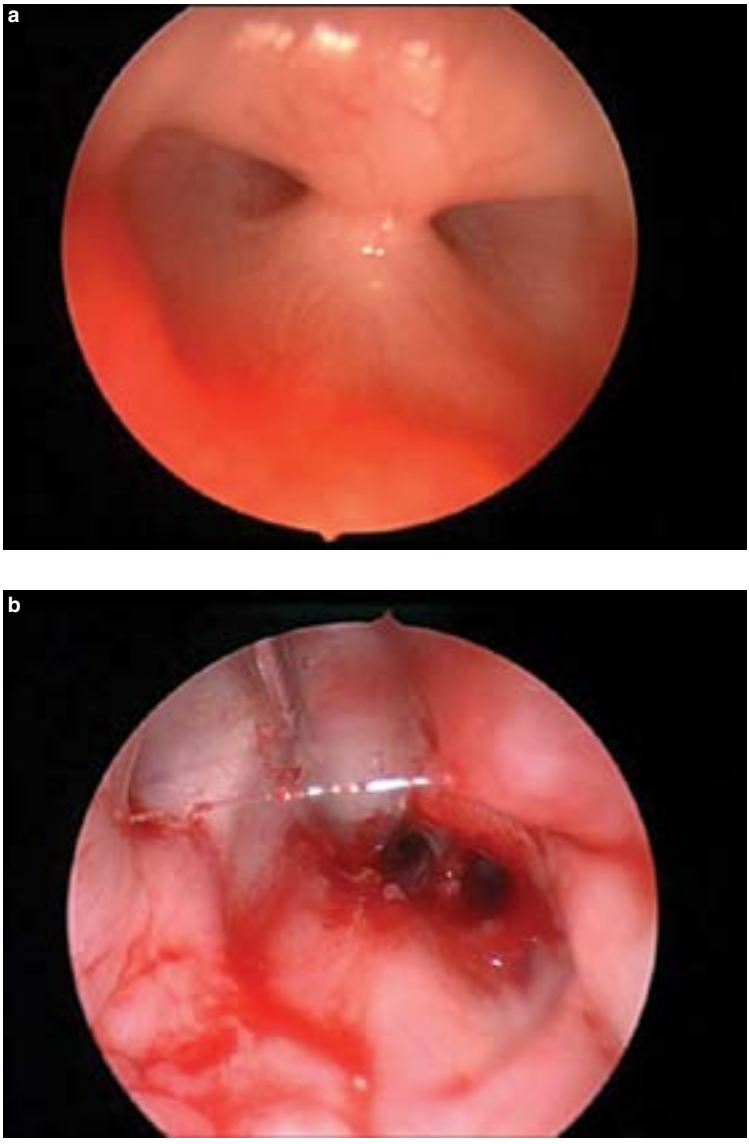


Figure 16-1. Choanal atresia in a neonate **(a)** as seen with a 120° telescope, and **(b)** following choanal atresia repair and dilation.

[CT] scan), and via direct nasopharyngoscopy. Consider associated syndromes when making a diagnosis (ie, CHARGE: coloboma of the eye, heart defects, atresia of the nasal choanae, retardation of growth or development, genital or urinary abnormalities, or ear abnormalities and deafness).

- Initial management
  - Insert an oropharyngeal airway.
  - Administer orogastric tube feedings.
  - Perform surgical repair with short-term nasal stenting.

Intraoral Obstruction

- Mandibular hypoplasia (micrognathia). Associated with:
  - Pierre Robin syndrome. Main features include:
    - cleft palate, retrognathia (abnormal positioning of the jaw or maxilla), and
    - glossoptosis (airway obstruction caused by backward displacement of the tongue base).
  - Treacher Collins syndrome. Typical physical features include:
    - downward-slanting eyes,
    - micrognathia (a small lower jaw),
    - conductive hearing loss,
    - underdeveloped zygoma,
    - drooping part of the lateral lower eyelids, and
    - malformed or absent ears.
  - Mandibular hypoplasia occurs when a normal-sized tongue falls posteriorly, obstructing the supraglottic airway.
  - Treatment: place the patient in a prone position. Rarely, a nasopharyngeal tube is needed.
  - The mandible grows faster in children, so by 3 months of age, the condition is usually resolved.
- Macroglossia
  - Associated with Beckwith-Wiedemann syndrome. Characteristics include:
    - macroglossia (large tongue),
    - macrosomia (above-average birth weight and length),
    - midline abdominal wall defects (omphalocele/exomphalos, umbilical hernia, diastasis recti),
    - ear creases or ear pits, and

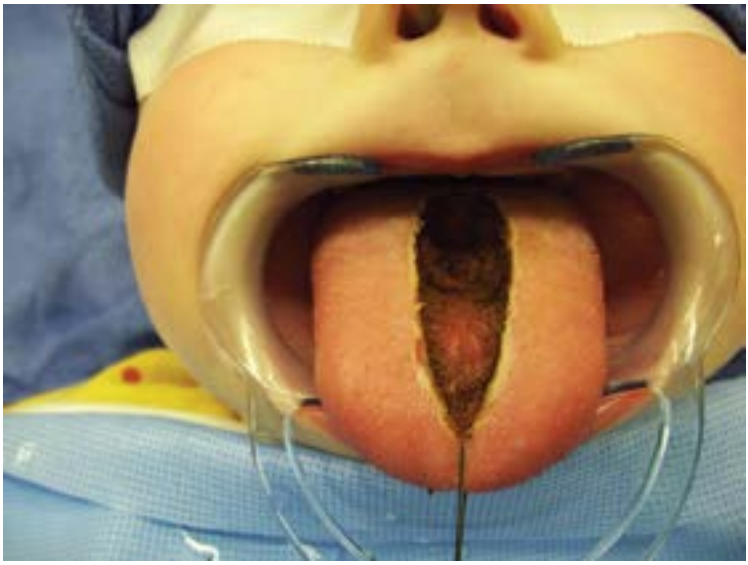


Figure 16-2. Midline partial glossectomy sparing the tip of the tongue in a child with macroglossia.

    - neonatal hypoglycemia.
  - Treat by placing the patient in the prone position to keep the tongue forward. A tracheostomy and a gastrostomy tube may be necessary.
  - Tongue reduction surgery may be performed. Reduce the bulk of the tongue without resection of the tip (midline glossectomy; Figure 16-2).
- Intraoral neoplasms
  - Types of intraoral neoplasms include lymphangioma, teratoma, aberrant thyroid gland tissue, and rhabdomyosarcoma (Figure 16-3).
  - Treatment approaches vary but excision with or without a temporary tracheotomy is often indicated.

Laryngotracheal Abnormalities

- Malformations
  - Laryngomalacia is a collapse of the supraglottic tissues (epiglottis, arytenoids) during inspiration.

- This is the most common cause of upper airway obstruction in an infant.
- Symptoms include inspiratory stridor, cyanosis, retractions and, occasionally, feeding difficulty.
- Laryngomalacia may not be present at birth but develops within the first 4 to 6 months of life.
- It worsens with agitation and supine positioning.
- It is milder when the patient is in the prone position with neck extended.
- Laryngomalacia is diagnosed with direct laryngoscopy (which will reveal an Ω-shaped epiglottis and supraglottic collapse with inspiration).
- Treatment is usually nonsurgical; place the infant in the prone position with neck extended.
- Temporary tracheotomy may be required for severe symptoms (this is necessary in fewer than 10% of patients).
- Symptoms typically resolve by 2 years of age.

° Laryngeal clefts may be limited to the deep interarytenoid notch or extend through the cricoid ring.
- Symptoms include respiratory distress, cyanosis, and aspiration pneumonia.
- Diagnosis is made by endoscopy.
- Treat with endotracheal (ET) intubation and gastrostomy tube. Later, surgical repair will be needed.

° Webs: thin, membranous, obstructing diaphragms usually located at the glottic level.
- Symptoms include airway obstruction at birth.
- Diagnosis is made by laryngoscopy.
- Treat with endoscopic excision.

° Atresia requires immediate tracheostomy.

° Laryngeal foreign bodies.
- Symptoms include sudden choking, loss of voice, dyspnea, inspiratory stridor, and retractions.
- Initial treatment consists of providing abdominal or chest thrusts.
- Surgical treatment involves removal of the foreign body by direct laryngoscopy.
- Cricothyroidotomy or emergent tracheotomy may also be necessary.

a



Figure 16-3. Oral hairy polyp in a newborn **(a)** and **(b)** coronal computed tomography scan of the mass. The lesion was soft and mobile and the infant was orally intubated with direct laryngoscopy. The lesion was surgically removed within the first 10 days of life without complications.

b



Cysts and Tumors

Laryngocele

- A laryngocele is a fluid-filled cyst of the larynx.
- Symptoms include inspiratory stridor.
- Diagnosis is made by laryngoscopy.
- Treatment consists of ET intubation and needle aspiration of the cyst and surgical unroofing (marsupialization).

Lymphangioma

- Lymphangioma is usually multiloculated and lined with endothelium.
- Airway obstruction is the only symptom.
- Treatment consists of staged excision.

Hemangioma

- Airway hemangioma is usually seen in infants less than 1 year old. This is often associated with cutaneous hemangiomas in a beard distribution.
- Located in the subglottic area.
- Symptoms include inspiratory stridor and respiratory distress.
- Diagnosis is made by laryngoscopy, CT scan, or magnetic resonance imaging.
- A hemangioma may regress spontaneously; administer oral or intralesional steroids if the patient is symptomatic.
- Oral propranolol is now the initial treatment of choice for infantile hemangiomas, including airway hemangiomas.

Papillomas

- Papillomas are benign neoplastic lesions associated with condyloma acuminatum in the mother at the time of birth.
- Symptoms include hoarseness, stridor, and dyspnea.
- Treatment consists of surgical excision; recurrence is common (virtually certain through puberty).
- Resection should be conservative.

Acquired Airway Obstructions

Acute Epiglottitis (Supraglottitis)

- Acute epiglottitis is an acute inflammatory swelling of the epiglottis caused by *Haemophilus influenzae* type B.
- It typically occurs in children ages 2 to 6 years old but can occur at any age, even through the adult years.
- Symptoms include inspiratory stridor, "sniffing" head position, systemic illness, drooling, dyspnea, and muffled voice; patients appear toxic with fever, tachycardia, tachypnea, and increased white blood cell count.
- Diagnosis is made with a radiograph of the lateral neck, which will show edema (evident as "thumb printing") of the epiglottis. If the patient is unstable, avoid radiographs and initiating intravenous access, and go directly to the operative suite. If radiographs are ordered, the surgical team should accompany the child throughout care.

- Treatment
  - Keep the patient calm; never attempt to visualize the throat in the emergency department.
  - Use ET intubation (usually for 3 days) in an operating room under general anesthesia with a surgeon present.
  - Perform tracheostomy if intubation cannot be accomplished (rare).
  - Initiate intravenous antibiotics (cefotaxime or ceftriaxone).

Croup (Acute Laryngotracheobronchitis)

- Croup is a viral inflammation producing subglottic edema.
- It is caused by parainfluenza viruses A and B.
- It occurs in children ages 3 months to 3 years old.
- Symptoms include barking cough, inspiratory and expiratory stridor, and substernal retractions (no drooling).
- Laboratory findings show increased white blood cell count with a right shift of the differential (ie, lymphocytosis).
- Neck radiographs show subglottic narrowing.
- Treat with humidification (croup tent) and racemic epinephrine (occasionally dexamethasone for severe cases).
- Avoid intubation or airway endoscopy if possible.

Foreign Bodies

- Laryngeal foreign bodies may result in complete airway obstruction.
- The most common airway site affected is the right mainstem bronchus.
- Symptoms include stridor, aphonia, cyanosis, hypoxia, coughing, wheezing, fever, and rhonchi.
- Diagnosis can be made with anterior-posterior and decubitus chest radiographs with the obstructed side down; radiograph will show hyperaeration on the side with the obstruction due to air trapping (Figure 16-4).
- Surgical treatment consists of extraction by direct laryngoscopy or rigid bronchoscopy under general anesthesia.

a



Figure 16-4(a–c). Chest radiographs in a child with a partial obstruction of the left mainstem bronchus due to a radiolucent object (vegetable matter). **(a)** Slight hyperinflation is seen on the posteroanterior.

Postintubation Subglottic Tracheal Stenosis

- Postintubation subglottic tracheal stenosis occurs when the cricoid forms the only complete ring in the airway and the area of smallest tracheal diameter. Stenosis usually occurs at the level of the ET tube balloon cuff.
- Diagnosis is made by laryngoscopy.
- Treatment: a tracheotomy tube will bypass the stenosis. Open and endoscopic repairs are used for correction (laryngotracheal reconstruction), but these require significant expertise and long-term postsurgical management.

b



Figure 16-4(b). Comparison of the right and left lateral decubitus films shows air trapping on the left decubitus film.

- Prevention: ensure there is a small air leak around the ET tube (leak should occur in all tubes at or below 20 cm H_2O and should be rechecked at regular intervals), stabilize ET tubes, and avoid reintubations if possible.

c



Figure 16-4(c). Left lateral decubitus film showing trapped air.

Surgical Procedures for Procuring an Emergency Airway

Cricothyroidotomy

- Avoid cricothyroidotomy in children under 12 years old.
- Needle cricothyroidotomy is a useful adjunct in children. It permits oxygenation and "buys time" until a definitive airway can be established.

- NOTE: In an emergency, needle cricothyroidotomy permits the patient to be oxygenated but does not permit adequate ventilation, so blood levels of carbon dioxide will increase, resulting in a worsening respiratory acidosis. Avoid use beyond 45 minutes.

Tracheostomy

- Avoid tracheostomy in an emergency setting because of the high incidence of serious complications.
- In infants and young children, the hyoid bone, laryngeal cartilage, and cricoid ring are closely approximated and often overlap.
- Never excise cartilage from the anterior tracheal wall.
- Make longitudinal (vertical) tracheal incisions through the second and third rings.
- Suture skin edges down to the tracheostomy using half vertical mattress sutures to "mature" the stoma.
- Traction sutures should be placed through the cut edges of the trachea, and ends taped to the skin.
- Accidental decannulation in the perioperative period is a frequent cause of mortality in children with a tracheotomy.

Laryngoscopy

- The most common indication for laryngoscopy is inspiratory stridor.
- Unique anatomical features of the infant larynx to note before performing laryngoscopy are as follows:
  - The infant larynx is situated more anteriorly (and superiorly) at birth.
  - An infant's epiglottis is at the level of the soft palate at birth.
  - The infant's larynx is narrowest in the subglottic region.
- Other indications for laryngoscopy include laryngomalacia, subglottic hemangiomas, papillomas, webs, foreign bodies, and cysts.
- The most common complication of laryngoscopy is laryngeal edema. Treat with humidification, racemic epinephrine, and steroids.

Bronchoscopy (Flexible or Rigid)

- Diagnostic uses of bronchoscopy include tracheomalacia and stenosis, extrinsic compression, tracheobronchial lavage (in cystic fibrosis patients), and foreign-body retrieval (rigid bronchoscopy).

Establishing an Airway

- Perform rapid-sequence intubation using etomidate plus succinylcholine (except in burns or crush injuries).
- In patients less than 12 years old, perform a tracheostomy through the second tracheal ring instead of a cricothyroidotomy.
- Estimate ET tube size using approximately the size of the child's little finger or the following:

$$(16 + \text{age in years})/4$$

- The distance (in centimeters) from lips to midtrachea: 12 + (age in years/2).
- An uncuffed ET tube is preferred in children less than 8 years old without conditions that may be associated with decreased lung compliance.

Trauma

- Fractures of the mandible (particularly subcondylar fractures) or maxilla (Le Fort fractures) can result in free-floating bone or soft tissue, which can prolapse and obstruct the airway.
- Dislocated teeth or debris may obstruct the airway. Carefully check a chest radiograph for displaced teeth (Figure 16-5).
- Initial maneuvers to secure an airway include jaw thrust, nasal trumpet (do not use if a fracture at the base of the skull is suspected), or oral airway.

Facial Bone Fractures

- In the absence of fractures leading to airway obstruction or severe bleeding, facial bone fractures do not need to be managed acutely but can be addressed up to 2 weeks after injury.
- Mandibular fractures may be associated with free-floating segments, resulting in prolapse of the tongue and airway obstruction.



Figure 16-5. Displaced tooth in the right mainstem bronchus (black arrow).

- If this occurs, the mandible may be maneuvered to an anterior position to allow airway management and fractures can be addressed later.
- Presenting symptoms include pain upon jaw opening, inability to open jaw (trismus due to masseter muscle spasm), and malocclusion (top and bottom teeth do not match up correctly).

  - Most mandibular fractures involve more than one site; isolated fractures are uncommon.
  - Many mandibular fractures are of the greenstick (incomplete) type and may be managed conservatively by closed reduction.
- Subcondylar fractures are generally managed with a soft diet and close observation.
- Nongreenstick body, angle, ramus, and parasymphysis fractures are managed with open reduction and internal fixation, together with maxillary-mandibular fixation (MMF) using intraoral wiring.
  - Care must be taken to avoid injuring permanent tooth roots when placing fixation device screws.
  - When wiring the jaws together (with wires or elastic bands), consider potential airway obstruction, emesis, and suitable caloric intake. Wire cutters should be available at the bedside at all times. Do not discharge patients with their jaws wired shut.
  - MMF duration should be brief in children, often no more than 2 to 3 weeks (adults undergo MMF for 4 to 6 weeks).
- Maxillofacial fractures
  - These fractures can wait up to 2 weeks for repair and are not urgent once bleeding is controlled and the airway is stable.
  - Classify using Le Fort classification (Figure 16-6).

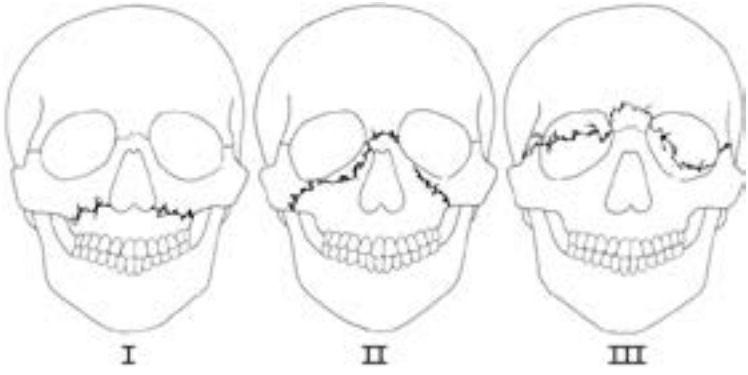


Figure 16-6. Le Fort facial fracture classifications.

    - Le Fort I: maxillary and alveolar fracture.
    - Le Fort II: pyramidal, nasal, and orbital fracture.
    - Le Fort III: craniofacial disassociation
  - Presenting symptoms include distorted facial appearance, facial swelling or bruising, malocclusion, and diplopia.
  - Significant hemorrhage often accompanies fractures of the maxilla and can be managed with nasal and oral packing after the airway has been secured.
  - Maxillofacial fractures may accompany cervical spine trauma and orbital or ocular trauma.
  - Use caution when placing nasal tubes (eg, nasogastric tubes, nasal trumpets) in patients with nasal or maxillary fractures due to the possible presence of a basilar skull fracture; this may result in inadvertent intracranial placement.
  - Assess the hard palate for fracture by palpation.
  - Management is limited to the facial support buttresses (medial and lateral), which are repaired with open reduction and internal fixation, and possibly MMF (temporary, short term).
- Nasal fractures
  - Nasal fractures are the most common facial fractures.
  - Diagnosis is made by manual palpation, if the nasal bones are mobile, fracture is present (plain films are not accurate as the suture is often confused for a fracture).
  - The decision to repair is based primarily on cosmetic considerations and is not urgent (it may be delayed up to 10 days) but should be performed by closed reduction as soon as the acute edema has subsided (usually within 5 days).
  - Septal hematoma may be associated with any nasal trauma and must be identified early to prevent cartilage necrosis.
    - Diagnose by visualizing the anterior septum either with a nasal speculum, otoscope, or other light source. A septal hematoma will appear as a dark purple mass (not subtle).
    - Treatment includes prompt incision and evacuation of the clot. Suture the mucoperichondrial flap in place over plastic or silicon splints or place a running septal whip stitch; administer systemic antibiotics while splints are in place (usually 5–7 days).

Base of the Skull and Temporal Bone Fractures

- Presenting symptoms include postauricular bruising (Battle's sign), orbital bruising (raccoon eyes), hearing loss or dizziness, facial nerve injury, hemotympanum, and leakage of cerebrospinal fluid (CSF), otorrhea, or rhinorrhea.
- Determining and documenting the length of time facial nerve function has been absent (ie, delayed versus immediate), if applicable, is important to optimize future facial nerve function.
  - Complete immediate-onset nerve damage requires direct nerve repair once life-threatening injuries have been addressed.
  - Managing incomplete facial nerve injuries (ie, some movement is visible) is not of acute interest and management can be delayed for up to 2 weeks.
  - Facial nerve repair, when indicated, is performed after decompression and under magnification with 9-0 suture.
  - Hearing loss may be conductive (mechanical) or sensorineural (nerve) and may be distinguished with a tuning-fork exam.
- Treat tympanic membrane perforation by keeping the ear clean and dry.
- A tympanic membrane perforation with purulent drainage (otorrhea) may be treated with nonototoxic antibiotic ear drops (eg, ofloxacin) for 7 to 10 days.
- Suspected CSF drainage from the ear should not be blocked (eg, with cotton balls, gauze, etc).
  - CSF otorrhea and rhinorrhea in the setting of a basilar skull fracture may be noted by the presence of clear, salty-tasting drainage that is exacerbated by sitting upright and leaning forward. Two concentric rings will be seen when a drop is placed on a piece of absorbent paper.
  - Treat with bed rest. Elevate the head of the patient's bed 15 to 30 degrees. The patient should avoiding straining, sneezing, and coughing.
  - Consider placing a lumbar drain if one is available.
  - Repair can be deferred until appropriate otolaryngological or neurosurgical expertise is available.

Laryngeal Trauma

- Laryngeal trauma is uncommon in pediatric patients because of the elevated position of the larynx underneath the mandible and the cartilaginous structure of the pediatric larynx (which is commonly ossified in adults).
- Presenting symptoms include hoarseness, stridor, crepitation, and subcutaneous emphysema.
- Acute management consists of appropriately securing the airway. Orotracheal intubation is usually possible; however, a tracheotomy is sometimes preferred in instances of severe laryngeal trauma. Definitive management may then be performed by the appropriate specialists.

Penetrating Neck Trauma

- Hemorrhage and airway injury are the primary concerns with penetrating neck trauma.
- The neck is divided into three anatomic zones to aid in management (Figure 16-7):
  - Zone 1
    - Boundaries: clavicle to cricoid membrane.

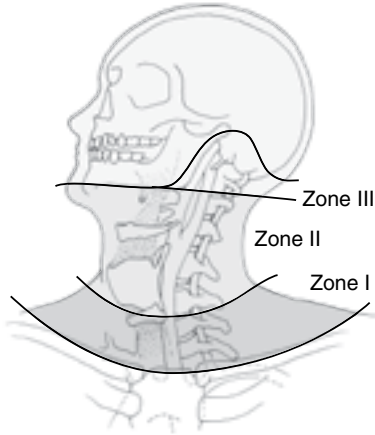


Figure 16-7. Neck zones.

    - Critical structures: common carotid artery, subclavian artery, apices of the lung, and the brachial plexus.
  - Zone 2
    - Boundaries: cricoid to angle of the mandible.
    - Critical structures: common and internal carotid arteries, internal jugular vein, esophagus, and trachea.
  - Zone 3
    - Boundaries: angle of mandible to base of the skull.
    - Critical structures: internal carotid artery, jugular vein.
- If the platysma muscle is not transgressed, no surgical management is initially indicated and close observation for neurologic changes, hematoma formation, or airway compromise is warranted.
- Diagnostic measures:
  - esophagoscopy,
  - bronchoscopy,
  - contrast (water-soluble) swallow study, and
  - CT angiogram.
- Zones 1 and 3 injuries
  - Management is selective based on clinical evidence of significant structural injury, such as significant bleeding, expanding hematoma, subcutaneous emphysema, hoarseness or stridor, hemoptysis, decreased pulses in the arm or neck, and mental status changes.
  - If the above are present, exploration with the appropriate expert (ie, vascular surgeon, otolaryngologist, neurosurgeon) is indicated to manage injury of involved structures.
- Zone 2 injuries
  - Presenting symptoms
    - air bubbling from the wound,
    - subcutaneous emphysema,
    - stridor,
    - dyspnea,
    - hypoxia, and
    - expanding hematoma.
- Management includes initial neck exploration and full endoscopy. Perform neck exploration via an incision along the anterior border of the sternocleidomastoid muscle to evaluate vascular structures, trachea, and the esophagus; repair as indicated.

- Tracheal injury: after the airway is secured, repair can be performed using 5-0, 6-0 nylon sutures, being careful not to enter the lumen of the trachea (if the airway is secure, evacuation to a suitable expert is strongly encouraged).
- Endoscopy should include laryngoscopy, bronchoscopy, and esophagoscopy.
- Esophageal injury may be difficult to diagnose because of delayed presentation, but should be considered in patients with unexplained fever or tachycardia and penetrating neck trauma in Zones 1 or 2.
  - Presenting symptoms include fever, tachycardia, and dysphagia.
  - Diagnose using chest radiograph, esophagoscopy, water-soluble contrast swallow studies, diatrizoate meglumine, and diatrizoate sodium solution swallow.
  - Initial management: allow nothing by mouth, explore and drain, give antibiotics, and refer the patient (if necessary) to the appropriate surgical specialty (general surgery, thoracic surgery, etc).
  - Definitive management consists of debridement with primary repair and feeding tube placement.

Soft Tissue Trauma

- Most injuries to the soft tissue of the face should be repaired primarily.
- Minimize the amount of tissue debridement, as even seemingly devitalized tissue may recover due to a robust blood supply.
- The cartilage should be meticulously covered with soft tissue.
- Consider antibiotics for *Pseudomonas* and *Staphylococcus* infection.
- Prompt incision and drainage of auricular hematomas with application of a bolster (two dental rolls or similar material sutured on opposite sides of the auricle) for 5 to 7 days to reduce the likelihood of hematoma reoccurrence and permanent cartilage damage.

Masses

Cervical Lymphadenitis

- Cervical lymphadenitis is the most common cause of a neck mass in a child.
- Etiology: usually *Staphylococcus* or *Streptococcus* infection.
- Treatment
  - Initially, administer antibiotics (eg, third-generation cephalosporin) to treat the primary cause (otitis media, pharyngitis).
  - Incise and drain fluctuant nodes.
  - Excise chronic lymphadenitis.
  - In addition to the bacterial infections cited above, the differential diagnosis includes human immunodeficiency virus, Epstein Barr virus, tuberculosis, atypical mycobacteria, and cat scratch fever (*Bartonella henselae*; Figure 16-8).



Figure 16-8. Cat scratch disease neck abscess in a child.

Lymphoma

- Lymphoma is the most common cause of malignant neoplasms of the head and neck, manifesting as firm, fixed nodes with generalized involvement (especially if present in the neck, axilla, or groin).
- Diagnosis is made by excisional lymph node biopsy.

Thyroglossal Duct Cyst

- Development of the thyroid gland originates at the base of the tongue in the foramen cecum and passes between the genioglossus muscles and through the hyoid bone to its normal anatomic position.
- A thyroglossal duct cyst is the most common congenital cyst of the neck.
- Thyroglossal duct cysts are usually discovered at 2 to 4 years of age, when baby fat starts to diminish.
- They are often asymptomatic, but recurrent infection is a characteristic problem due to communication with the pharynx.
- Thyroglossal duct cysts appear as a mass located in the midline at or below the level of the hyoid bone that moves up and down with swallowing.
- Differential diagnosis includes: lymphadenopathy, dermoid cyst, and aberrant thyroid tissue (obtain a thyroid ultrasound if the presence of a normal thyroid gland in is question).
- Treatment
  - Provide antibiotics for active infection.
  - Perform needle aspiration of abscesses.
  - Definitive treatment: perform elective surgical excision of the cyst and tract to the pharynx, in continuity with the central portion of the hyoid bone and attached tract to the base of the tongue (Sistrunk operation), with ligation of the foramen cecum.

Branchial Cleft Cysts

- Branchial cleft cysts are congenital fistula resulting from malformation or persistence of the second (most common) or third branchial cleft; abnormalities of the first branchial arch are associated with facial clefts (eg, cleft palate).

- First branchial cleft sinuses communicate with the eustachian tube.
- Second branchial cleft cysts extend from the anterior border of the lower third of the sternocleidomastoid muscle superiorly, then inward between the carotid bifurcation, entering the posterolateral pharynx just below the tonsillar fossa.
- The third branchial cleft tracks lateral to the carotid bifurcation.
- Symptoms include:
  - a painless nodule at the anterior border of the sternocleidomastoid muscle,
  - drainage from the external auditory canal (first cleft sinus),
  - external fistula with drainage of clear fluid from the lateral neck (second cleft), and
  - abscess formation in the lateral neck.
- Consider a third or fourth branchial cleft cyst in pediatric patients presenting with acute thyroiditis.
- Pathology: cysts are lined with squamous and columnar epithelium, cartilaginous remnants, and cystic dilatations.
- Treatment of second branchial cleft anomalies is as follows:
  - Initially, treat infection (if present) with antibiotics to cover *Staphylococcus* and *Streptococcus* organisms.
  - Perform complete surgical excision of the cyst and tract.
  - A lacrimal duct probe inserted through the external opening, as well as injection of a small quantity of methylene blue, will help define and facilitate dissection of the tract.
  - Use a series of small, transverse, "stair step" incisions, rather than a long, oblique incision.
  - The marginal branch of the facial nerve may be injured by intraoperative retraction.

Lymphatic Malformations (Cystic Hygroma)

- Cystic hygromas are congenital malformations resulting in sequestration or obstruction of developing lymphatic channels.
- They are usually posterior to the sternocleidomastoid muscle of the neck (posterior triangle). Other sites include:
  - axilla,
  - groin,
  - mediastinum, and

  - retroperitoneum.
- Cysts are usually multiloculated, may "infiltrate" deep structures of the neck (tongue, mouth floor), and are lined by endothelium.
- Infected cysts may cause airway compromise by compressing the trachea.
- Cysts may contain nests of vascular tissue (benign lesions).
- Characteristics
  - Soft and compressible.
  - Transilluminate.
  - Usually present at birth and grow proportionally with the child; sudden enlargement later may be due to hemorrhage or infection.
- Diagnosis is made by ultrasound, chest radiograph, or CT scan.
- Complications include:
  - airway compromise;
  - disfigurement;
  - purplish discoloration (resulting from hemorrhage into the cyst);
  - infection (*Staphylococcus* or *Streptococcus*), which may cause rapid enlargement and airway compression; and
  - post-operative recurrence.
- Treatment includes conservative surgical resection.
  - Complete surgical resection is rare because the lesion is usually multilocular (especially lesions above the hyoid) and there is no well-defined cleavage plane between the lesion and normal tissue.
  - Repeated partial excisions with preservation of all adjacent critical structures may be required.
  - Drain wound postoperatively by closed suction.
  - Needle aspiration of accumulated fluid may be required postoperatively.
  - Avoid injury to the facial nerve (cranial nerve VII).
  - Injection of sclerosing agents (eg, OK-432, which is derived from group A *Streptococcus pyogenes*) may yield good results in cases with primarily macrocystic disease; sclerotherapy may also be used in conjunction with operative excision before and after the operation.

Miscellaneous Conditions

Otorrhea

- Drainage of purulent fluid from the ear may represent acute or chronic otitis media with a tympanic membrane perforation or otitis externa (swimmer's ear); cholesteatoma and temporal bone tumors may also present with chronic otorrhea.
- Treat by gently cleaning the ear canal with suction or cotton swabs, then apply antibiotic eardrops. Consider oral antibiotics for patients with systemic symptoms and signs.

Acute Otitis Externa

- Diagnosis: severe pain with manipulation of the auricle, foul-smelling discharge, and ear canal edema.
- Treat by gently cleaning the ear canal, then administer antibiotic eardrops or 2% acetic acid drops for 10 days. Prescribe oral analgesics.
- A cotton or cellulose ear wick may be placed in an edematous ear canal to ensure the otic drops are properly delivered.
- Refer the patient to a specialist if the status of the tympanic membrane is unknown, if symptoms persist despite appropriate treatment, or for hearing loss or vertigo accompanying otorrhea.

Hearing Evaluation

- Hearing status may be tested using a 512-Hz tuning fork. Use one or more of the following:
  - Weber test: Place the shaft of a vibrating tuning fork on the midline of the head (forehead, bridge of nose, upper central incisors) and ask the patient to point to the ear where the sound is loudest. In a normal hearing individual, the sound is midline. The sound is heard louder in an ear with conductive hearing loss; it may be heard in the better-hearing ear in patients with severe sensorineural hearing loss.
  - Rinne test: Place the vibrating tuning fork shaft on the mastoid bone behind the auricle, then direct the tines toward the external auditory canal in the air. Ask the patient

which sounds louder. Air conduction is normally better than bone conduction. If bone conduction is better (ie, the patient hears better with the tuning fork to the mastoid), then a conductive hearing loss is likely in the affected ear.

Hearing Loss in Children

- The most common cause of hearing loss in young children is chronic otitis media (fluid in the middle ear space). Other causes include congenital and acquired sensorineural hearing loss.
- Trauma is an uncommon cause of hearing loss but may impact hearing through a tympanic membrane perforation, ossicular chain disruption, or acoustic barotrauma that damages the inner ear.
- Foreign bodies.

Congenital Wryneck (Torticollis)

- Congenital wryneck is evident in the early months of life due to fibrosis of the sternocleidomastoid muscle.
- Physical examination reveals tender, palpable swelling in the lower part of the sternocleidomastoid muscle, with the patient's head extended, and rotated toward the opposite side as the mass.
- Treatment includes:
  - neck radiograph to exclude vertebral anomalies (Klippel-Feil syndrome),
  - active and passive stretching exercises, or
  - surgical transection of the belly of the sternocleidomastoid muscle if the above is unsuccessful (rarely necessary).
- 20% of those with congenital wryneck will have associated hip dysplasia.

Epistaxis

- Anterior septal vessels are the most common source of epistaxis in children.
- Treat by firmly pinching the nasal ala for 10 minutes (by the clock!); ice may be applied to the bridge of the nose during this time.

- Oxymetazoline may be sprayed into the nostrils or applied to cotton packing or strips and inserted into the nose to control epistaxis that is refractory to pressure.
- Apply hemostatic packing (Gelfoam [Pharmacia and Upjohn Co; Kalamazoo, Michigan] wrapped in Surgicel [Ethicon US, LLC; Somerville, New Jersey] or tamponade using a balloon device if bleeding persists despite several minutes of direct pressure).
- Consider a posterior source of epistaxis for persistent bleeding; secure the airway first and then pack the nasopharynx via the mouth until definitive care becomes available.
- Prevention: instruct the patient to avoid nose picking, use humidification, and apply petroleum jelly or other ointment (eg, mupirocin). NOTE: The patient will frequently vomit bright red blood swallowed from the nasal source.

Acute Bacterial Sinusitis

- Acute bacterial sinusitis is a complication of an acute upper respiratory infection in 5% to 7% of children.
- Symptoms include one of the following:
  - upper respiratory infection symptoms (nasal discharge and/or daytime cough) for more than 10 days without improvement,
  - worsening symptoms after initial improvement, or
  - sudden onset of purulent nasal discharge and fever (≥ 39°C) for at least 3 days.
- Diagnosis is based on clinical evaluation; imaging is not necessary. Reserve sinus CT for suspected orbital or intracranial complications.
- Etiology: the typical infectious etiologies of acute bacterial sinusitis in children are *Streptococcus pneumoniae*, *Haemophilus influenzae*, and *Moraxella catarrhalis*.
- Treatment: amoxicillin with or without clavulanate is the first-line treatment for acute bacterial sinusitis. Ceftriaxone or other second- or third-generation cephalosporins are alternatives. Saline nasal irrigations and oral or topical decongestants may also be helpful. Antihistamines are not useful for treating acute sinusitis.

Chapter 17

Orthopedics

Orthopedic trauma, although rarely life-threatening, is often accompanied by injury to neurovascular structures as well as to other organ systems. Assessing and treating airway, breathing, and circulatory impairment takes priority in all cases. Immobilizing injured extremities will decrease pain, bleeding, and the risk of injury to adjacent structures.

Resources in Roles 1 to 3 military medical treatment facilities are focused on adult orthopedics; equipment tailored to pediatric sizes and specific problems may not be available. Weather, sanitation, and ease of transport may also alter treatment; for instance, external fixation of closed long-bone fractures may be elected over open fixation to obviate infection, or external fixation may be more practical than closed treatment in a heavy cast.

Medical providers should familiarize themselves with local medical care resources for follow-on treatment. Subsequent care must be compatible with available local civilian resources as well as with culturally acceptable norms. A general knowledge of the indigenous cultural views on health, gender, and specific conditions (eg, amputations and congenital deformities) is helpful in directing care for pediatric civilian casualties.

Short-term intervention may have limited impact and cultural norms may affect efforts to improve outcome. Interventions and their complications may leave patients in worse condition after treatment than if they had not received treatment at all.

Epidemiology

Types of Orthopedic Care

- Trauma

- Children are subjected to the same mechanisms of injury as war fighters. In the past two decades, the leading etiologies of pediatric orthopedic trauma seen in deployed military facilities are
  - blast injury (ie, direct contact with an explosive device),
  - penetrating injury,
  - thermal injury,
  - blunt force injury, and
  - congenital malformations/reconstruction.
- Deployed orthopedic surgeons may be asked to evaluate and treat mild to severe congenital anomalies. Healthcare providers must use good judgment when initiating reconstructive treatment because there may be limited means for follow-up or follow-on treatment.

- Infection
  - Pediatric musculoskeletal infections may be caused by pathogens endemic to the geographic area of operations.
  - Wound infections may be caused by common environmental microorganisms.
    - *Staphylococcus aureus* remains the most common cause of musculoskeletal infection throughout the world.
    - *Salmonella typhi* has been reported to be the most common infecting organism in Africa.
    - *Acinetobacter baumannii* is common in southwest Asia. It is found in soil and can live on open surfaces for a number of days, enabling it to spread. Patients with open wounds and those on ventilators are susceptible to this multiple drug-resistant organism.
    - *Klebsiella pneumoniae*, an organism that lives in water, is typically acquired in a hospital setting and is often associated with people with poor nutrition and those with slightly depressed immune systems.
    - *Pseudomonas aeruginosa* thrives in moist environments and is a threat to patients with several kinds of injuries, including burns. *Pseudomonas* and *Staphylococcus epidermidis* are the most common causative agents of infection in extramedullary implants in local hospitals in Iraq.

        - Clostridia are gram-positive, anaerobic, spore-forming bacilli found in high density in cultivated, rich soil. *Clostridium perfringens* is the most common cause of gas gangrene and food poisoning. *Clostridium difficile* is responsible for pseudomembranous colitis after long-term antibiotic use.
    - Osteomyelitis and septic joints can be hematogenous or result from direct inoculation. The causative organisms are those found in the particular environment.
        - The first principle of treatment is to evacuate and drain purulent material when it is entrapped.
        - Eradicating osteomyelitis or a septic joint will require long-term antibiotic therapy. Remote facilities or indigenous hospitals may not have the requisite laboratory support to follow laboratory values. Surgeons may be required to evaluate a patient's response to treatment and determine treatment duration. Whenever possible, treatment initiated in the military setting should be coordinated with local, indigenous medical support. Be mindful that the microbial profile and antibiotic availability in deployed areas may differ substantially from that in the continental United States.

Difference in Levels of Trauma

Although common pediatric orthopedic traumas may present to a military medical facility, most cases will be more complex. In civilian and military settings in the continental United States, the receiving facility often provides emergency care and transports the patient to a higher-level facility for definitive care. In theater, the major orthopedic care for local civilians will occur at the military facility, followed by transportation to a lower-level facility.

Amputations

- Children sustain amputations from the same mechanisms of injury as war fighters.
    - Exsanguination is the immediate concern.

- Explosive munitions with penetration and concussive blast effects create a large zone of injury with extensive contamination and the potential for associated neurovascular injury that may affect the level of final amputation.

- Indications for partial or complete traumatic amputation include
  - irreparable vascular injury or failed vascular repair with an ischemic limb;
  - life-threatening sepsis due to local infection, including clostridial myonecrosis; and
  - severe soft tissue or bone injury beyond functional recovery.
- Amputations should be done at the most distal level of viable tissue (in contrast with traditional amputation levels; eg, below the knee, above the knee, etc) to preserve as much limb as possible.
  - A longer residual limb is most desirable for prosthetic fitting and will serve the amputee best if prosthetic fitting is not possible.
  - The ability to return to the operating room for further treatment should influence the level of amputation and extent of debridement.
  - Children have a remarkable ability to heal wounds that initially appear nonviable.
  - Second-look surgery may preserve limb length and the ability to provide soft tissue coverage.
  - Open length-preserving amputation has two stages.
    - Initial: At this stage, bone resection is completed at the lowest level possible.
      - The residual limb is left open with large soft-tissue flaps, perhaps of questionable viability.
      - Negative-pressure dressings, if available, are one means of decreasing soft tissue and skin retraction and of stabilizing the residual limb pending a second-look surgery and are preferred to skin traction. Negative-pressure dressings allow abundant formation of granulation tissue and reduce the need to transfer soft tissue to treat defects.
    - Reconstruction: The goal at this stage is to achieve sufficient healing for optimum function and prosthetic fitting.

- Civilian pediatric amputees will undergo this phase in country, unlike military patients who will be evacuated out of the combat zone for reconstruction in a stable environment.
- All viable skin and soft tissue distal to the amputated bone should be preserved for future wound closure. These "flaps of opportunity" can be used to add length to the residual limb, regardless of irregularity.
- Because viable soft-tissue coverage determines residual limb length, guillotine-type amputations are not advised and require revision to a more proximal level.

Technique

- A tourniquet is used to limit blood loss and preserve intravascular volume in trauma patients. There is very little literature on the use of tourniquets in the pediatric population (see Further Reading at the end of this chapter). General guidelines are as follows.
  - Place the tourniquet on the most proximal portion of the limb.
  - Use the widest cuff possible suitable for the limb, location, and procedure.
  - Use a specifically designed limb protection sleeve for the cuff, if available. If not, use two layers of tubular stockinette, slightly stretched but not tight.
  - Apply the tourniquet snugly over the sleeve.
  - Determine the occlusion/systolic blood pressure and set the tourniquet pressure to 50 mmHg above that (average is 175 mmHg).
  - Exsanguinate the extremity by elastic bandage or gravity, as appropriate for the case.
  - If bleeding persists after cuff inflation, increase the cuff pressure in increments of 25 mmHg until the bleeding stops.
  - Minimize tourniquet time (**no more than 2 h without intervals of 15-min deflation time**).
  - Remove the cuff and sleeve as soon as possible after the tourniquet is deflated. Alternatively, an Esmarch bandage may be used to exsanguinate and control limb hemostasis.

Three wraps of 3- or 4-inch Esmarch bandage provide hemostasis for surgery in a safe pressure range (around 230 mmHg) at the desired tourniquet location.

- Sterilize the entire extremity.

- Debride nonviable bone and devascularized soft tissue.
- Suture ligate major arteries and veins.
- Locate major nerves, provide gentle traction, and transect proximal to the level of amputated bone; ligate major nerves.
- Preserve muscle flaps, but do not suture.
- Full debridement of a blast injury may require extending incisions longitudinally to remove contamination along fascial planes.

Managing Local Amputees

- Definitive care will be provided in theater.
- Following the principles of the Red Cross surgeons working in relatively stable environments, local civilian pediatric patients will undergo delayed primary closure once their wounds are clean.
- Prevent skin retraction of open residual limbs using skin traction or—preferably—a negative-pressure dressing (eg, VAC, Kinetic Concepts, Inc, San Antonio, Texas), until closure is possible. Skin traction may be accomplished through the classic technique of benzoin-secured stockinette and 1 to 2 lb of weight (Figure 17-1). In select situations, skin retraction can be prevented by placing large, loose trauma sutures with bolsters or vessel loops and skin staples at the wound margins. Preserving viable skin flaps, even if they are irregular, aids in closure and is preferable to skin grafting.
- Acceptance of an amputee patient and the type of prosthesis the patient receives vary depending on the local culture. Existing local resources for prosthetic fitting may be limited.
- When applicable, early prosthetic fitting, especially in upper-extremity amputations, promotes best functional use of the prosthesis. Frequent prosthetic changes are expected.
- As a result of rapid growth rate and the quantity of young healing bone, various long-term problems may arise, especially in below-the-knee amputations, such as

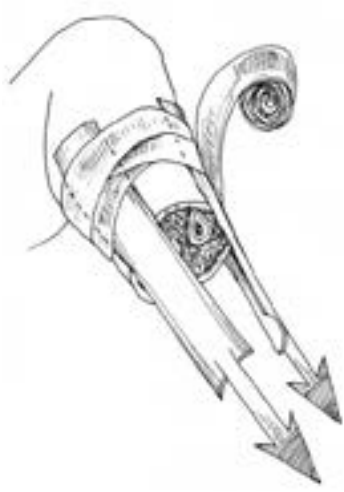


Figure 17-1. Cut-away view of stockinette skin traction.

- anterior bowing associated with the distal element pointing medially;
- varus bowing with the distal element pointing medially;
- heterotopic bone formation, requiring revision; and
- overgrowth phenomena in which the fibula may outgrow the tibia, causing bursa formation overlying the fibula and prominent bone spicules to project beneath or protrude out from the skin.

- These problems may be prevented or controlled by synostosis of the distal fibula and tibia, which results in an end-bearing residual limb (this procedure should not be performed until the soft tissues have fully healed). Additionally, transarticular (rather than metaphyseal) amputations in skeletally immature patients avoid this complication.

Compartment Syndrome

Children with compartment syndrome do not exhibit the same symptoms as adults. The "six Ps" of acute compartment syndrome (pallor, pulselessness, paralysis, paresthesia, pain, poikilothermia) do not have the same diagnostic application

with children. The "three As" are more applicable to pediatric compartment syndrome (anxiety, agitation, and increased need for analgesia). Pediatric trauma patients should not have regional anesthesia, which may mask a developing compartment syndrome, and excessive narcotics should be avoided in patients at risk of developing compartment syndrome. Elevating fractured limbs above the level of the heart will minimize tissue edema and decrease the need for analgesics.

When compartment syndrome is a concern, compartmental pressures should be measured immediately using a needle/transducer instrument (eg, Intra-Compartmental Pressure Monitor, Stryker Corporation, Kalamazoo, Michigan). Pressures above 30 mm Hg are abnormal.

Compartment syndrome is a clinical diagnosis. If there is clinical evidence of compartment syndrome, the compartments should be released emergently. **Caution**: Obtunded patients and patients with nerve injuries or regional blocks who may not respond appropriately display atypical symptoms. These patients need thorough monitoring; the surgeon should have a low threshold for compartment release if compartment syndrome is suspected clinically.

- Two incisions are recommended for four-compartment fasciotomy of the leg—medial and lateral.
  - The lateral incision will release the anterior and lateral compartment.
    - The incision should be long and centered over the anterolateral leg.
    - Incise down to fascia.
    - Identify the intermuscular septum. The septum is readily palpable by running a finger from medial to lateral and vice versa, feeling for the indentation. Make a transverse incision and use a freer instrument to confirm the presence of the intermuscular septum.
    - After the intermuscular septum has been identified, divide the fascia over the anterior and lateral compartments.
    - Identify and protect the superficial branch of the peroneal nerve, which may exit from the fascia of either compartment through a fascial defect.

- The medial incision should be just posterior to the posterior border of the tibia.
  - Avoid injury to the saphenous nerve and vein. Enter the deep posterior compartment by releasing the fascia in this interval to expose the muscles of the deep compartment.
  - The superficial posterior compartment is easier to enter proximally on the leg.
  - After release, do not close the fascia wound. The skin may retract without tension and skin grafting may be required.
  - A "Jacob's ladder," using staples and vessel loops, may be constructed to provide skin tension.
  - A sterile dressing or a wound vacuum may be applied.
- The two most common pitfalls in performing fasciotomy are failure to make a sufficiently long skin incision and failure to completely open all four compartments.

Fractures

Evaluating Fractures

- Obtain the patient's history, perform a physical examination to fully assess injuries, and establish vascular and neurologic status of the patient's extremities.
- Fractures are separated into six classification categories (Figure 17-2).
- Obtain radiographs of the adjacent joints (above and below the fracture in the case of a long-bone fracture), with images in two planes.
- Examine and cover open wounds, preferably with a sterile dressing soaked in povidone-iodine or other antiseptic.
- Early administration of antibiotics and delayed surgical management of open fractures do not increase the risk of subsequent infection.
- Splint the involved extremity, including the joints above and below, for a long-bone fracture.
- Fracture reduction should be done with adequate anesthesia or analgesia.

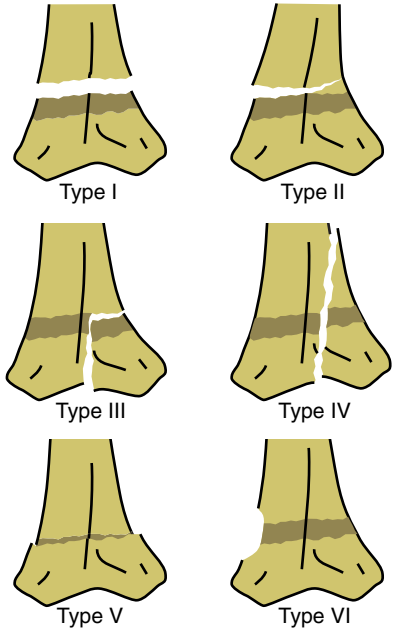


Figure 17-2. Salter-Harris classification of fractures involving the growth plate. Type I: transverse fracture through the physis. Type II: fracture through the physis and metaphysis. Type III: fracture through the physis and epiphysis. Type IV: fracture through all three (physis, metaphysis, and epiphysis). Type V: physeal compression fracture.Type VI: peripheral physeal injury.

- After reduction and application of a cast or external fixator, reevaluate the limb's vascular status and sensory and motor nerve function.
- Children's fractures remodel 1 degree per month for the first 24 months.
- Children have an incredible capacity to remodel malunited fractures. The degree of remodeling potential corresponds to the child's remaining growth and the location of the fracture. In infants and children, the remodeling potential is typically large. In adolescents, growth may be estimated by comparing the patient's size with his/her parent's.

- Fractures around the wrist, shoulder, and knee have a remarkable ability to remodel. Fracture remodeling near the elbow and hip after age 4 years is poor.

Open Fractures

- Open fractures sustained in a combat area are produced by small arms (bullets) and explosive munitions (improvised explosive devices, mortars, artillery, land mines, grenades, or bombs).
- The most common battlefield injury is multiple fragment wounds that involve only the soft tissue.
- Open fractures caused by weapons of war are more severe than those seen in a noncombat setting.
- Initial treatment for open fractures
  - Evaluate the wound while the patient is under anesthesia.
  - Surgically incise the skin and fascia to inspect the soft tissue and fracture site.
  - Excise devitalized tissue or debris.
  - Copiously lavage with a physiological solution to decontaminate and remove debris, dead tissue, or hematoma.
  - All wounds should initially be left open and closed at a later date.
  - Negative-pressure wound therapy may be a useful adjunct, especially for more extensive wounds.
  - Administer systemic antibiotics and tetanus prophylaxis appropriate for the wound.
  - If there is a skin defect, perform coverage as a second, staged, operative procedure only after the wound is clean and free of necrotic tissue.
  - Soft-tissue coverage procedures should be planned and performed in a stable environment.

Long-Bone Fractures

- General
  - Internal fixation of pediatric fractures in theater is rarely, if ever, indicated due to operative conditions and an enhanced potential for infection.

- Based on the patient's size and available equipment, external fixation may be desirable for stabilizing long-bone fractures in theater. Appropriately sized fixators may not be available; the "pins in plaster" technique may be used to maintain length.
- Casting remains an acceptable treatment option, provided alignment can be maintained. Cast wedging is particularly helpful to control pediatric fractures that angulate in a cast.
  - Opening wedges are preferred because they increase the space available for swelling and can substantially reduce fracture angulation.
  - Using fluoroscopy, mark the point of angulation of the fracture. For a single-plane correction, the wedge should be done in the concavity of the deformity. The circumference of the cast is split greater than 50% at the distal end of the proximal fragment. The cast is spread and wedges placed in the gap to maintain the cast in the new position. Neurovascular status is monitored distal to the wedge. The wedge is assessed radiographically and is overwrapped, when acceptable.
- Skeletal traction is also useful for some fractures.

Upper Extremity Fractures

- Proximal humerus fractures
  - The majority of proximal humerus fractures in the pediatric age group are treated conservatively with a sling and swathe for roughly 2 weeks.
  - The proximal humerus has a considerable ability to remodel. Reduce fractures with greater than 25 degrees of angulation in patients within 2 years of skeletal maturity.
  - Gradual return to normal function is allowed once pain subsides.
- Midshaft humerus fractures
  - Use a coaptation splint with a sling and swathe for comfort.
  - This may be changed to a Sarmiento-type brace at 2 weeks (if available) instead of definitive treatment in long arm cast.
- Supracondylar humerus fractures

- Significantly displaced fractures (Gartland types 2 and 3) require closed reduction and percutaneous pinning; crossed medial and lateral pins (rather than two or more divergent or two to three divergent lateral pins) are adequate. Varus or valgus deformity of less than 10 degrees and extension deformity of less than 15 degrees is acceptable.
- Place the extremity in a long arm cast for 3 weeks and consider bivalving the cast if the extremity swells.
- Remove pins after 3 weeks and allow the patient to begin activities as tolerated.
- Avoid immobilization in more than 90 degrees of elbow flexion; this may lead to ischemic contracture.
- Type 2 fractures can sometimes be reduced and held without pinning with a long arm cast (see precautions above).

- Lateral condyle fractures
  - Lateral condyle fractures are often difficult to diagnose in younger populations; when in doubt, diagnose with an arthrogram. The preferred location is posterior, into the olecranon fossa.
  - Perform the arthrogram.
    - Palpate the olecranon, being mindful of the location of the ulnar nerve.
    - Using sterile technique, insert the needle proximal to the tip of the olecranon until you hit bone, then withdraw the needle by a millimeter and inject the contrast material, ideally under fluoroscopy with a lateral view of the elbow. Avoid using excessive contrast material.
    - If the fracture is not displaced or does not enter the joint, percutaneous fixation may be used. This will facilitate patient transport and will decrease the risk of fracture displacement. Two or three laterally-based divergent pins may be used to percutaneously fix a lateral condyle fracture.
  - Open reduction is indicated if the fracture enters the joint and there are more than 2 or 3 mm of displacement.
  - Use a lateral approach; avoid stripping the posterior soft tissue attachments off the fragment because blood supply enters posteriorly.

- Reduce the fragment and pin with two or more Kirschner wires.
- Immobilize in a long arm cast for 4 to 6 weeks, then remove pins after healing is noted.
- Lateral condyle fractures are notorious for nonunion.

- Elbow dislocation
  - Reduce an elbow dislocation as soon as feasible, as dislocations become more difficult to reduce with time. There is a 10% neurologic injury rate, usually involving the ulnar nerve.
  - Evaluate the elbow's range of motion under fluoroscopy, if possible, after reduction.
  - Immobilize the elbow in a posterior splint for 2 weeks, then the patient may begin motion. If the elbow is unstable with extension, immobilize it in appropriate degrees of flexion to maintain reduction.
  - Beware of medial epicondyle fractures, especially the entrapped medial epicondylar fragment. Suspect an epicondyle fracture when there is continued instability, joint subluxation, severe pain, and lack of medial epicondyle on anteroposterior radiographs of the elbow. Half of elbow dislocations cause a medial epicondyle fracture.
  - Medial epicondyle fractures rarely require treatment, regardless of displacement, unless they are entrapped in the joint or the patient has significant ulnar nerve dysfunction (in which case, open reduction and pin—as opposed to screw—fixation is indicated).
  - Use a 0.062-inch Kirschner wire instead of a 4.0 cannulated screw, with or without a washer. If the epicondylar piece fragments, it may be stabilized with suture.
  - Closed reduction of a trapped medial epicondyle fragment can be accomplished using the Roberts method.
    - Attach the epicondylar piece to the flexor pronator mass.
    - Extend the wrist and supinate.
    - Give valgus stress to elbow; the fracture may reduce if done acutely.
  - Most medial epicondyle fractures heal without operative treatment. A substantial portion that are treated without surgery heal with a fibrous union that is satisfactory.

- Radial neck fractures are common. Closed—as opposed to percutaneous or open—reduction may be indicated.
  - Acceptable reduction is less than 30 degrees of angulation.
  - The risk of avascular necrosis is significant for fractures that must be treated in open fashion due to the blood supply to the radial head.
  - Monteggia fractures: Beware of isolated ulnar fractures in children or ulna bowing without fracture. The radial neck should point toward the capitellum on any view of the elbow.
  - Radiographs may show an obvious olecranon fracture or an apophyseal sleeve avulsion injury. Treatment for children without forearm extension or displacement should be operative, with open reduction and internal fixation using a tension band with stainless steel or suture.

- Forearm and wrist fractures
  - Forearm and wrist fractures may involve the radius, ulna, or both, and may occur at the distal, middle, or proximal forearm.
  - Remodeling potential is greatest in younger patients and in distal areas near the physis.
    - Expect an angular correction of approximately 1 degree per month or 10 degrees a year for 2 years.
    - Rotational deformities do not correct with growth; bayonet apposition of up to 1 cm is acceptable if the patient is less than 8 to 10 years old. If the initial displacement is outside this range, fracture reduction and casting are recommended.
    - In general, immobilization consists of 4 weeks in a long arm cast, followed by 2 weeks in a short arm cast. Immobilization duration varies depending on fracture healing and age.
  - Angulation greater than 20 degrees decreases the range of pronation and supination.
  - Torus and buckle fractures are stable.
  - Consider intramedullary nailing for proximal ⅓ radial shaft fractures. Intramedullary nails should be 30% of the bone's diameter.

- Wrist fractures (at the distal third of the forearm) can be treated with 3 to 6 weeks of short arm casting, depending on the age of the child and the fracture type.
  - Carpal fractures are rare in children. If the patient has negative radiographs but tenderness over the snuff box, treat as a scaphoid fracture with a thumb spica case and repeat radiograph in 10 to 14 days.
  - For metacarpal injuries, avoid rotational deformity by buddy taping the fingers and flexing the metacarpal phalangeal joint to 90 degrees.
  - Angulation is better tolerated in the ulnar hand (10 degrees in the index and middle finger, 40 to 50 degrees in the ring finger and small finger).
- Fingertip amputations in children have a remarkable ability to heal. Err on the side of less aggressive treatment. For children less than 4 years old, a composite graft consisting of the defatted fingertip may be cleaned and sutured to cover the defect. The fingertip typically turns black but heals underneath.

Lower Extremity Fractures

- Pelvic fractures (see Further Reading for additional guidance)
  - Overall, pelvic fractures in pediatric patients are rare.
  - Pelvic fractures are usually caused by a high-energy mechanism that results in other life-threatening injuries. Comprehensive workup using advanced life support principles is indicated.
  - Children have greater plasticity, thicker cartilage, and more mobile joints than adults, and their vessels tend to spasm and not bleed (life-threatening hemorrhage is rare).
  - Children have a lower mortality rate (10%–15%) from pelvic fracture than adults. Blood transfusions are required in 10% to 15% of children with pelvic fractures.
  - The majority of children with pelvic fractures can be treated nonoperatively with a pelvic compression wrap or external fixator and have a much better prognosis than adults with pelvic fracture.
  - Imaging

        - Take radiographs of the anteroposterior pelvis (inlet, outlet, and Judet views).
        - Computed tomography (CT) scan is preferred, especially with image reconstructions.
        - If an associated urethral or bladder injury is suspected, obtain a cystourethrogram.
    - Treatment is based on age; fracture location, type, and stability; and concomitant injuries.
        - Most pelvic injuries in children are treated nonsurgically and heal uneventfully.
        - Surgical indications include intraarticular acetabular or triradiate cartilage displacement of more than 2 mm, and pelvic ring displacement with more than 2 cm of limb length discrepancy.
        - External fixation may be used for unstable fractures.
    - Complications
        - Acetabular fracture or triradiate injury may lead to a dysplastic acetabulum and early degenerative changes.
        - Sacroiliac joint pain.
- Femur fractures
    - Certain current acceptable and standard treatments, such as internal fixation with plates, may not be reasonable in an austere environment because of infection risk and limited equipment availability.
    - Treatment is typically based on the age and size of the patient and the availability of equipment (Table 17-1).

Table 17-1. Guidelines for Acceptable Reduction in Femur Fractures

Age (y)	Varus/Valgus	Procurvatum/ Recurvatum	Shortening
0–2	30°	30°	15 mm
2–5	15°	20°	20 mm
6–10	10°	15°	15 mm
11 and older	5°	10°	10 mm

- Birth to 6 months old: Use a spica cast for diaphyseal fractures and a long leg cast for supracondylar fractures. The Pavlik harness that is recommended in the noncombat environment may not be available in theater.
- 6 months to 12 years old: Use an external fixator or pins in plaster. Submuscular bridge plating is a good option in a developed healthcare system, but may not be appropriate in theater. Skeletal traction may be used where external fixation is not available or not advised (eg, while a child is confined to bed); it requires limited operating room technology.
- 12 years and older: Use an external fixator. Intramedullary nailing or bridge plating are good options in a developed healthcare system, but may not be appropriate in theater. Kirschner wires may be used to stabilize transverse fractures. Smooth or treaded Kirschner wires may be used to transfix fractures after open reduction. After fixation with the Kirschner wire, cut flush with cortex. Plan to immobilize the joint above and below the fracture treated in this fashion.

  - Proximal tibial metaphyseal Cozen fractures may develop a valgus deformity at 12 to 24 months after injury. Decrease this risk by providing a slight varus mold to the cast. Reduce the fracture and place the limb in a long leg cast with 20 to 30 degrees of knee flexion for 6 weeks. More knee flexion makes it difficult to provide a varus stress. Most valgus deformities will remodel on their own and not require surgery. Discuss the growth deformity with the patient's parents as soon as possible.

- Tibial shaft fractures
  - The majority of tibia fractures are treated with closed reduction and long leg casting.
  - Acceptable alignment: 50% apposition, less than 1 cm shortening, and 5 to 10 degrees of angulation in the sagittal and coronal planes.
  - A long leg cast is applied with slight (10–20 degree) ankle-plantar flexion and 45 degrees of knee flexion.
  - Look for an increasing varus deformity in the tibia fracture with an intact fibula.

- Time to healing is based on age. Neonates heal in 2 to 3 weeks, children in 4 to 6 weeks, and adolescents in 8 to 12 weeks.
- External fixation and open reduction with internal fixation may be used if clinically indicated (eg, in the case of severe comminution, open fractures, etc).

- Ankle fractures
  - The majority of ankle fractures are Salter-Harris-type injuries and can be treated with closed reduction and a short leg cast.
  - Displaced fractures (greater than 2 mm) that traverse the physis and involve the joint may require reduction and internal fixation.
  - Physis may be crossed if the patient is near skeletal maturity.
  - Tillaux fractures and triplane fractures are more complex ankle fractures and may need to be evaluated by CT scan to discern fracture pattern and displacement. Displaced Tillaux or triplane fractures are treated with open reduction and internal fixation. In an austere setting, open reduction with Kirschner wires and casting is an option. For children who are near skeletal maturity, crossing the physis is not concerning.
  - Growth arrest
    - Physeal bar formation can cause angular and limb-length discrepancy.
    - Growth arrest is more closely linked to initial displacement than Salter-Harris classification.
    - Harris-Park growth arrest lines should be visible 6 months after injury and indicate growth resumption. The growth arrest lines should be parallel to the physis; growth arrest lines that angulate toward the physis may indicate a physeal bar or partial growth arrest.
    - Consider CT to evaluate the presence and extent of physeal bar.
    - Consider excising the bar based on its size, deformity/discrepancy, and growth remaining.

Further Reading

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Chapter 18

Thoracic Cavity

General Approach to Thoracic Injuries

Incidence

Of pediatric trauma and combat injuries, 8% to 25% involve the lung, mediastinal structures (heart, aorta, esophagus, and bronchus), diaphragm, or chest wall. Blunt injuries are the most common, usually due to motor vehicle accidents or pedestrian-versus-motor vehicle collisions, falls, or abuse. Penetrating injuries are rare but are more common depending on the amount of violence or combat within a region. Blast injuries are potentially due to a combination of blast wave, blunt, and penetrating mechanisms and may be caused by ignition of flammable liquids or explosion of an improvised explosive device.

Clinical Presentation

- Up to two-thirds of pediatric trauma patients with thoracic injuries will have stable vital signs upon presentation.
- Ribs in pediatric patients are incompletely mineralized, making them more pliable than those of an adult. Therefore, rib fractures signify a large amount of kinetic force to the chest and underlying structures.
- Symptoms will vary depending on mechanism, anatomic location of injury, and concomitant injuries to other systems, such as the head, neck, or abdomen.

Evaluation

- The physical examination for pediatric thoracic injury follows the guidelines of advanced trauma life support and proceeds as follows:

    - perform primary survey and resuscitation, followed by
    - secondary survey, then
    - transfer to appropriate echelon of care.
- Clinical predictors of thoracic injuries with blunt trauma are hypotension, tachypnea, external chest wall signs of contusions or lacerations, decreased breath sounds, and decreased Glasgow Coma Scale score.
- Unlike in adults, severe thoracic injuries can be present in children without rib fractures.
- To diagnose, use ultrasound, plain chest radiographs, computed tomography (CT) scans (these are more sensitive than plain radiographs but are rarely available in developing countries or at forward-deployed stations), or other adjuncts, if available (eg, magnetic resonance imaging, bronchoscopy, echocardiogram).

Treatment

- Initial treatment for most thoracic injuries can generally be addressed as follows.
    - Establish patent airway and oxygenation.
    - Provide assisted ventilation, if required.
    - Resuscitate for active bleeding, but use fluids judiciously for pulmonary contusions or lacerations.
    - Provide adequate analgesics, especially with multiple rib fractures.
    - Give antibiotics for suspected infection or injury to the tracheobronchial tree or esophagus.

Thoracic Injuries Based on Anatomic Site

Lung

- Pneumothorax
    - Types
        - Simple: collapse of lung without open wound or mediastinal shift.
        - Open: rare case of a collapsed lung due to open wound to pleural space.
        - Tension: surgical emergency where the presence of a one-way valve between the lung and pleural space results in

a mediastinal shift, tracheal deviation, and flattening of the diaphragm and subsequent hypotension as a result of decreased cardiac filling. Not well tolerated due to the mobility of mediastinal structures in pediatric patients.

- Clinical presentation
  - Any open or penetrating wound on the chest wall should be a concern for a pneumothorax.
  - Other signs include absent or decreased breath sounds, tachypnea, respiratory distress, and hypoxia.
  - Tracheal deviation, engorged neck veins, or unilateral absence of breath sounds with hypotension suggest a tension pneumothorax.
- Diagnosis
  - Clinical diagnosis can be made when there is absence of breath sounds, respiratory distress, hyperresonance, decreased oxygen saturations, pallor, or cyanosis.
  - Ultrasound and plain chest radiograph may also be used for diagnosis; however, tension pneumothorax requires emergent treatment first, *before* a chest radiograph.
- Treatment
  - For tension pneumothorax, treat emergently with needle decompression at the second intercostal space in the midclavicular line. Insert a large-bore needle or an angiocatheter over the rib to decompress. For adolescent patients, adequate needle length (1.5–2 inches) is required.
  - Perform a chest tube thoracostomy into the fourth intercostal space at the midaxillary line by incising the skin over the fifth rib and tunneling subcutaneously to the fourth intercostal space.
    - Refer to the table in the front of this book for age-appropriate thoracostomy tube sizes. Consider inserting a pigtail catheter in lieu of a thoracostomy tube, if available (not recommended for evacuation of a hemothorax).

- Hemothorax
  - Hemothorax is most often due to laceration and hemorrhage resulting from injury to the lung, intercostal artery, internal mammary artery, or a mediastinal blood vessel.

- Symptoms
  - decreased breath sounds, dullness to percussion;
  - hypotension and tachycardia; and
  - respiratory distress.
- Diagnosis: chest radiograph, showing opacification of the affected side, blunting of the costophrenic angle, or loss of the diaphragm border.
- Treatment
  - A chest tube will treat most cases of hemothorax (see description for chest tubes in Pneumothorax section). Because of the small diameter of the drainage holes, pigtail catheters tend to clot frequently and are not recommended for treating hemothorax. They may be considered for evacuating air or some effusions.
  - Emergent thoracotomy is indicated for penetrating trauma if the following signs are present:
    - Rapid loss of 20 cc/kg or more than 20% to 25% of estimated blood volume from chest tube drainage.
    - Continuous bleeding that is greater than 2 to 4 mL/kg/h over 2 to 4 hours.

- Pulmonary contusion
  - Pulmonary contusion is the most common type of blunt injury in children, occurring in two-thirds of patients.
  - Children's compliant chest wall transmits impact forces to the intrathoracic structures, often without external evidence of injury to the chest wall (ie, absence of rib fractures).
  - Parenchymal hemorrhage and edema produce intrapulmonary shunting (alveolar ventilation and pulmonary perfusion [V/Q] mismatch) that results in hypoxia, atelectasis, and pneumonia.
  - Symptoms
    - Rib fractures indicate a significant impact force to the chest and probable underlying pulmonary contusion.
    - Pulmonary contusion may initially present with minimal symptoms, but may progress with manifestations of respiratory distress.
  - Diagnosis
    - Plain radiographs will demonstrate opacification in the area of direct trauma. Blast injuries may show diffuse

opacification due to blast wave injury.
    - CT scan is rarely indicated initially.
  - Treatment consists of:
    - observation and supportive care (oxygen),
    - analgesics (consider intercostal nerve blocks) if ribs are fractured,
    - judicious use of intravenous fluids,
    - effusion or hemothorax drainage, and
    - careful observation for infection or pneumonia, which increase complication rates. Intubation and ventilator assistance may be indicated based on injury severity and initial treatment response.
  - Most pulmonary contusions resolve within 10 days.
  - Pneumatocele (air-filled area of pulmonary parenchyma) is a possible long-term complication that usually resolves in 4 to 6 months without surgical intervention.
- Lung laceration
  - Lung laceration is most common after penetrating trauma or rib fractures.
  - Clinical presentation
    - Lung laceration can present with signs and symptoms associated with hemothorax and pneumothorax.
    - The most serious complication of lung laceration is an air embolus.
  - Suspect lung laceration in any penetrating trauma to the thorax.
  - Treatment
    - Place a chest tube for associated hemothorax or pneumothorax.
    - Thoracotomy may be required for massive hemorrhage, large pneumothorax not responsive to chest tube thoracostomy, or air embolus.
- Rib fractures and flail chest
  - Rib fractures signify significant trauma to the chest wall and underlying structures.
  - Flail chest refers to the paradoxical motion of the chest wall due to multiple fractures of adjacent ribs, resulting in inadequate ventilation of the underlying lung

("pendelluft").
- Clinical presentation includes
  - localized pain, tenderness, and crepitus at fracture sites;
  - respiratory distress and hypoxia; and
  - paradoxical motion of the chest wall.
- Rib fractures and flail chest are commonly associated with underlying lung contusion.
- Diagnosis
  - Plain radiographs are used to evaluate for fractures and possible associated contusion, hemothorax, and pneumothorax.
  - Fractures or contusions may not be visualized initially; it may be necessary to obtain repeat imaging studies at 48 hours.
- Treatment consists of supportive care with analgesics (narcotics, nonsteroidal antiinflammatories, intercostal blocks, epidural), supplemental oxygen, and chest physiotherapy. Ventilator support with continuous positive airway pressure or positive end-expiratory pressure on assisted ventilation may be required.

Heart and Pericardium

- Pericardial tamponade
  - Pericardial tamponade is the result of fluid accumulation within the pericardial space that prevents adequate preload filling of the right atrium.
  - Pericardial tamponade is a rare occurrence. Clinical presentation includes:
    - Beck's triad (hypotension, muffled heart sounds, and distended neck veins),
    - pulsus paradoxus, and
    - tachycardia.
  - Diagnose with ultrasound. A focused assessment with sonography for trauma (FAST) scan will demonstrate lucency (fluid) within the pericardial sac.
  - Treatment
    - Needle pericardiocentesis is a temporizing measure only. Insert a long needle via the subxiphoid approach, angled at 45 degrees toward the patient's left shoulder or tip of

the left scapula. Aspiration of even a small volume of blood will result in improved hemodynamics. In most instances, this blood will be defibrinated and will not clot.
    - Perform a "subxiphoid window" incision, grasp and incise the pericardial sac, and place a pericardial tube to relieve or prevent a tamponade.
    - Perform an emergent left posterolateral thoracotomy if the patient does not respond to pericardiocentesis.
- Myocardial contusion
  - Myocardial contusion is the most common type of blunt cardiac injury that can cause arrhythmias and death. The right ventricle is most commonly affected.
  - Myocardial contusion may be asymptomatic.
  - Myocardial contusion is usually associated with blunt trauma to the anterior chest. Unexplained tachyarrhythmia is the most common symptom (supraventricular tachycardia and ventricular fibrillation are common).
  - Diagnosis
    - Electrocardiogram will show nonspecific ST-T wave changes.
    - Creatinine phosphokinase (muscle band fraction) will be elevated, as will troponin I and T levels (most accurate).
    - Echocardiogram will show decreased ejection fraction and septal wall motion abnormality.
  - Treatment
    - Observe patient for 24 hours on a cardiac monitor, or transfer patient to higher echelon of care.
    - Administer vasopressors if hypotension ensues.

Ruptured Diaphragmatic Hernia

- Blunt or penetrating trauma to the diaphragm may result in herniation of the bowel contents into the chest.
- Clinical presentation
  - Occurs on the left side in more than 80% of cases. The liver serves to buttress the right hemidiaphragm.
  - There are no specific clinical signs, but ruptured diaphragmatic hernia can present with respiratory distress.
  - Traumatic diaphragmatic hernias may be associated with injury to the spleen, liver, kidney, gastrointestinal tract,

and chest wall.
- Delayed diagnosis is common.
  - Plain radiographs may show an elevated or ill-defined hemidiaphragm, an abnormal gas pattern, bowel within the left chest above the diaphragm, or the course of a nasogastric tube passing above the level of the diaphragm. Initial films should include lateral views and can be normal in 30% to 50% of cases, thus repeat films should be obtained if a ruptured diaphragmatic hernia is clinically suspected.
  - A CT scan of the chest and abdomen can confirm diagnosis.
- Treatment
  - In the case of acute trauma, perform emergent laparotomy and repair the diaphragm using nonabsorbable suture material.
  - In the case of a delayed repair, a transthoracic approach to repair the diaphragm may be preferred because of intraabdominal adhesions.

Aortic Injury

- Aortic injury rarely occurs in children and is usually due to rapid deceleration that causes a tear at the level of the ligamentum arteriosum (obliterated ductus arteriosus), or the takeoff of the left subclavian artery.
- Patients often present with a history of rapid deceleration with fractures to the first, second, or third ribs or the scapula.
- Diagnose using chest radiograph, which will show abnormalities that may include
  - mediastinum widening,
  - pleural or apical cap,
  - deviation of the trachea to the right,
  - deviation of the esophagus (or nasogastric tube) to the right,
  - obliteration of the aortopulmonary window,
  - obliteration of the aortic knob,
  - widened paratracheal stripe,
  - elevation of the right mainstem bronchus,
  - depression of the left mainstem bronchus, and
  - left hemothorax.
- CT scan and transesophageal echocardiography can provide

further detail.

- Treatment
  - Stabilize and transfer the patient to a facility with a vascular or cardiothoracic surgeon.
  - Repair can be delayed until after severe injuries to the central nervous system and solid organs are addressed.
  - Careful control of blood pressure by beta blockade may be required. Esmolol, administered as a continuous infusion and titrated based on frequent or continuous blood pressure determinations, is the preferred drug in this instance.

Trachea and Bronchus Injury

- Tracheal and bronchial injuries are more common than injuries to the great vessels and are usually due to blunt trauma.
- Symptoms include respiratory distress, hypoxia or cyanosis, hemoptysis, and massive air leakage from the chest tube.
- Diagnosis
  - Chest radiograph will show massive subcutaneous and mediastinal emphysema and failure of the lung to re-expand after chest tube placement, especially if the lung falls to the lower half of the pleural cavity.
  - Flexible bronchoscopy may be used to diagnose injury and facilitate selective intubation over the injury site.
- Treatment
  - Establish an airway using endotracheal intubation with or without flexible bronchoscopy.
  - Drain via a thoracostomy tube if a significant pneumothorax is present.
  - Transfer the patient to a medical facility with high-frequency ventilation capabilities if the patient cannot be oxygenated.
  - If the injury covers more than a third of the circumference of the trachea, perform an emergent posterolateral thoracotomy and repair operatively using interrupted, nonabsorbable sutures, if possible. Lung resection may be necessary.
  - Most small lacerations or injuries will spontaneously heal without surgery.

Penetrating Esophageal Injuries

- Penetrating injury is rare. Clinical presentation includes fever, chest pain, tachycardia, hematemesis, and subcutaneous emphysema along the neck.
- Diagnosis
  - Plain chest radiographs may show mediastinal air, pneumothorax, or pleural effusion.
  - Upper gastrointestinal study with water-soluble contrast material is usually definitive.
  - CT scan of the neck, chest, and abdomen with contrast may be helpful.
- Treatment
  - Stabilize the airway.
  - Transfer the patient to a medical treatment facility with the appropriate surgical capabilities.
  - Administer antibiotics.
  - Penetrating injury is best treated within 12 hours by thoracotomy, surgical repair, and drainage.
  - Delayed diagnoses may require cervical diversion, gastrostomy tube placement, and chest tube drainage.

Infections of the Lung and Pleura

Complications of Bacterial Pneumonias (see Chapter 29, Infectious Diseases)

Pneumatocele

- A pneumatocele is a small, thin-walled cyst resulting from necrosis and liquefaction of lung parenchyma.
- It is usually seen in young children with *Staphylococcus aureus* pneumonia but can also occur with group B *Streptococcus* and *Haemophilus influenzae* pneumonia.
- Most pneumatoceles are asymptomatic and incidental findings. Pneumothorax or pyopneumothorax can be complications after rupture.
  - Diagnosis is made by chest radiograph or CT scan, which will show intrapulmonary air pockets without air-fluid levels.
  - Differential diagnosis includes congenital lung cysts.

- Pneumatoceles usually resolve spontaneously (whereas congenital cystic lesions do not).

Lung Abscess

- The most common cause of lung abscess is pulmonary aspiration. It may also result from operations on the upper respiratory tract (eg, tonsillectomy, tooth extractions).
- The most common sites are the superior segment of the right lower lobe (supine position), posterior segment of the right upper lobe (lying on right side), and basilar segments of lower lobes (upright position).
- Typical organisms that cause lung abscess are anaerobes (most common), *Staphylococcus aureus*, *Streptococcus viridans*, and group A hemolytic *Streptococcus* and *Pseudomonas*.
- Lung abscess can occur due to congenital pulmonary adenomatoid malformation, bronchogenic cysts, or intralobar sequestration.
- Clinical presentation includes fever, chills, malaise, and productive cough; chest pain; hemoptysis; and weight loss and anorexia.
- Diagnosis can be made by chest radiograph and CT scan, which show an intrapulmonary cavity with an air–fluid level. White blood cell count or C-reactive protein will also be elevated.
- Treatment
  - Administer antibiotics for 6 to 8 weeks.
  - Perform bronchoscopy with direct aspiration of fluid.
  - Provide chest physiotherapy.
  - Acutely ill infants may require percutaneous pigtail catheter drainage if they are unresponsive to antibiotic therapy.
  - Indications for surgical resection (usually a segmental resection) are as follows:
    - Chronic abscess lasting longer than 3 months or thick-walled (greater than 4–6 cm) abscesses.
    - Bronchial stenosis.
    - Progression to empyema.
    - Massive hemoptysis.

Empyema

- Empyema is the accumulation of purulent fluid in the pleural space.
- Stages
  - Exudative or acute: thin pleural fluid, pH less than 7.2, low cell count.
  - Fibropurulent: many polymorphonuclear leukocytes, pH less than 7.2, decreased glucose, deposition of fibrin, fluid loculations.
  - Organizing: thick exudates, constricting fibrous peel encapsulates the lung.
- Organisms that commonly cause empyema include *Streptococcus pneumoniae, S aureus,* and *H influenza*, but the organism can vary depending on the region.
- Early treatment with intravenous antibiotics may prevent the effusion from becoming infected and forming an empyema.
- Anaerobic empyemas are associated with the highest mortality rate.
- Symptoms include tachypnea, fever, and persistent cough.
- Diagnosis is made by physical examination, chest radiograph, CT scan, ultrasound, and thoracentesis (differential diagnosis of transudate), which will reveal the following:
  - pH less than 7;
  - turbid or purulent appearance;
  - protein greater than 3 g, or pleural fluid protein to serum protein ratio greater than 0.5;
  - glucose less than 40 mg/dL;
  - lactate dehydrogenase (LDH) greater than 200 units/L, or pleural fluid LDH to serum LDH ratio greater than 0.6;
  - cell count with large numbers of polymorphonuclear leukocytes; and
  - Gram stain showing organisms.
- Treatment consists of intravenous antibiotics and either of the following:
  - Nonloculated fluid: thoracostomy tube drainage.
  - Loculated fluid: video-assisted thoracoscopic surgery or possibly thoracotomy with pleural decortication.

Mediastinal Masses

- Common causes of masses of the anterior mediastinum include ectopic thyroid, lymphoma, teratomas, and masses involving the thymus.
- Common causes of masses of the middle mediastinum include bronchogenic cysts, cardiac tumors, lymphadenopathy, lymphoma, pericardial cysts, and vascular abnormalities.
- Common causes of masses of the posterior mediastinum include esophageal duplication, meningomyelocele, neurogenic tumors (eg, neuroblastoma), and sarcomas.

Miscellaneous Conditions

- Spontaneous pneumothorax
  - Spontaneous pneumothorax results from a ruptured subpleural apical bleb.
  - Clinical presentation
    - The typical patient is a thin, lean, adolescent male, often a smoker.
    - Diminished breath sounds are present on the ipsilateral chest.
    - Tympany to percussion may be heard on auscultation.
    - There may be a mediastinal shift to the contralateral side (if under tension), which may decrease the venous return, resulting in hypotension and tachycardia.
  - Diagnosis is made by posteroanterior and lateral chest radiographs. Use chest CT scan to assess for the presence of apical blebs.
  - Treatment
    - If the patient exhibits symptoms of a tension pneumothorax: perform emergent needle decompression through the second intercostal space at the midclavicular line.
    - If the size of the pneumothorax is estimated to be less than 15%: observe and give oxygen by mask.
    - If the size of the pneumothorax is estimated to be greater than 15%: insert a small intrathoracic (pigtail) catheter and attach to a suction drainage device or Heimlich valve.

        - Treatment for recurrence or persistent air leak: use video-assisted thoracoscopic surgery for apical pleurectomy (endostapler) and pleurodesis (mechanical or chemical).
- Hemoptysis
    - Hemoptysis may be caused by pulmonary hypertension, bronchiectasis, a foreign body, congenital pulmonary malformations, or infections.
    - Hemoptysis usually stops spontaneously; however, treatment may include bronchoscopic localization and selective bronchial artery embolization. If those are unsuccessful, perform lobectomy.

Chapter 19

Vascular Surgery

Introduction

The majority of congenital vascular abnormalities are benign and require no treatment. Traumatic vascular injuries in children in Iraq and Afghanistan usually involve the extremities, with the brachial artery being the most commonly injured vessel. It is important to recognize that the energy generated by high-velocity, fragmented projectiles produces large soft-tissue cavitation with the potential for direct or indirect vascular injury, with concurrent injuries to adjacent soft tissue, nerves, and bony structures.

Hemangiomas

- Benign tumors of vascular tissue, vascular birthmarks, and vascular malformations are the most common tumors of infancy. They are considered a type of hamartoma and develop from abnormal angiogenesis.
- Hemangiomas are usually solitary, located on the head or neck, and occur most often in females. They
  - typically appear within a week after birth;
  - may be superficial lesions that are raised, bright red, and bosselated; and
  - may be deep lesions that are raised and appear blue-purple.
- The natural history of a hemangioma is characterized by 8 to 12 months of rapid growth followed by involution occurring over 1 to 5 years.
- Complete resolution is usually achieved by age 5 to 7 years.
- Classification
  - Neonatal staining ("stork's bite"): light pink lesion on the back of the neck in the midline; usually fades spontaneously.

- Salmon patch: a light pink variety of intradermal hemangioma that sits level with the skin surface, blanches with pressure, and does not change over years. Can be treated with cover-up creams or laser treatment.
- Capillary hemangioma (port-wine stain, nevus flammeus): hyperkeratotic patches (abnormal nerve endings) on the facial skin (deep in the dermis) that are supplied by cranial nerve V (trigeminal). These lesions are permanent (they do not enlarge or regress) and may be associated with Sturge-Weber syndrome (indicating central nervous system involvement). They can be treated with laser ablation.
- Spider angioma: small, central arteriole with a network of radiating intradermal capillaries; these usually appear at age 3 to 4 years and regress spontaneously.
- Juvenile hemangioma: congenital vascular malformations that usually regress spontaneously after a period of rapid growth. This is a soft, spongy, nontender, reticular pattern of blood vessels in skin over a mass. Treatment consists of observation.
- Strawberry (capillary) hemangioma: these intensely red lesions undergo a period of very rapid growth; complications may develop before regression.
- Congenital arteriovenous (AV) fistulas: multiple and diffuse lesions, 50% of which occur in the head and neck. Treatment consists of intermittent pneumatic compression and complete surgical resection.
- Arterial hemangioma: pulsatile masses that exhibit bruits or thrills and may be associated with sign bleeding or marked regional gigantism. Treatment consists of surgical resection of all AV shunts.
- Venous malformations (cavernous hemangioma): spongy, subcutaneous swellings with a bluish discoloration; these do not regress and may grow to gigantic size, causing disfigurement. Treat with injections of sclerosing agents (eg, tetradecyl sulfate).
- Kasabach-Merritt syndrome: rapidly enlarging, solitary lesion that presents with hemolytic anemia, thrombocytopenia, and coagulopathy. Treat with interferon.

    - Visceral hemangioma: most commonly occurs in the liver and manifests with hepatomegaly, anemia, coagulopathy, and high-output heart failure. Treatment is indicated for large and symptomatic lesions; use steroids, interferon, or embolization.
- Diagnose with complete blood count, platelet count (red blood cells and platelets can be trapped/sequestered, resulting in lower peripheral white blood cell and platelet counts), computed tomography scan with intravenous contrast, magnetic resonance imaging, or angiogram (rarely indicated).
- Complications
    - Ulceration (most common complication).
    - Bleeding from ulceration.
    - Cosmetic concerns.
    - Infection.
    - Kasabach-Merritt syndrome: rapidly enlarging, solitary lesion that presents with hemolytic anemia, thrombocytopenia, and results in coagulopathy.
    - Compromise of vital structures (eg, airway, eye).
    - Disseminated intravascular coagulation after surgical resection.
    - Internal organ involvement.
        - Liver: hepatomegaly, congestive heart failure.
        - Lung: hemoptysis, recurrent pneumonia.
        - Treatment for internal organ involvement includes administering prednisone or cyclophosphamide and performing hepatic artery embolization or ligation.
- General treatment principles
    - Observation only unless complications arise.
    - First-line treatment is propranolol or steroids.
    - Embolization can be useful for treating liver lesions and as a preoperative adjunct to surgical resection.
    - Kasabach-Merritt syndrome is often treated with vincristine.
    - Surgical treatment is only indicated in very rare cases that fail to respond to less invasive treatments.
    - Laser (argon) treatment is especially useful for port-wine stains and head and airway lesions, but is not indicated for strawberry capillary or cavernous hemangiomas.

Lymphangioma

The lymphatic vessels drain protein-rich fluid leaked from capillaries and return it to the blood. Lymph travels through the cisterna chyli, to the thoracic duct, and on to the left internal jugular vein at its junction with the subclavian vein. Lymphangiomas develop as a result of abnormal embryologic development of the lymphatic system. The neck and axilla are common sites. Unlike hemangiomas, lymphangiomas do not regress spontaneously.

- Types include cystic hygroma and lymphedema.
- They are soft, nontender, and grow with the child.
- Diagnosis is made by ultrasound.
- Types of benign lymphatic tumors
  - Cystic hygroma (see Chapter 16, Face and Neck): although these are benign, cystic hygromas can be very difficult to resect because of their close approximation to critical structures (ie, nerves and vasculature).
  - Lymphedema: an abnormal accumulation of lymphatic fluid in interstitial fluid due to abnormal development (aplasia or hypoplasia of lymphatic channels) or obstruction. There are three types:
    - congenital (Milroy's disease; present at birth),
    - praecox (appears in adolescence), and
    - tarda (occurs in middle age).
- Treatment
  - Excision is only indicated for cosmesis, compression of vital structures (eg, airway), and to avoid the remote risk of infection.
  - In the remote setting, observation alone is appropriate for small to moderate asymptomatic lesions.
  - Large lesions often require a combination of staged excision and sclerotherapy. Recurrence is common.
  - Complications include infection (eg, lymphangitis, cellulitis) and lymphangiosarcoma.

Venous Disorders

- Embryology: right umbilical vein regresses before birth (this may account for a gastroschisis defect occurring to the right of the umbilicus).
- AV malformations
  - Truncal malformations arise from major arterial branches. They are hemodynamically active with large communications and often form on the upper extremities, head, or neck.
  - Diffuse malformations have multiple small communications, are seldom hemodynamically active, and commonly exhibit a bruit.
  - Malformations are bright red, exhibit increased skin temperature, and manifest an audible bruit.
  - Complications include bleeding, distal ischemia, and congestive heart failure.
  - Diagnose by arteriography.
- Treatment can include surgical excision (high recurrence rate), use of compression garments, selective embolization, and proximal ligation (contraindicated, but ligating multiple small feeding vessels may help).
- Congenital anomalies of central veins
  - Duplication of superior vena cava.
  - Anomalous pulmonary venous return (total or partial).
    - Infant is cyanotic at birth and has a right-to-left shunt.
    - Associated with atrioseptal defect.
  - Absence of inferior vena cava, resulting in venous drainage through the azygos system; associated with situs inversus.
  - Preduodenal portal vein: often associated with duodenal anomalies and malrotation, but also associated with situs inversus.
- Diagnose the above disorders with Doppler ultrasound.
- Treat thrombotic complications of congenital anomalies of central veins with heparin anticoagulation or, in the case of acute thrombosis of major veins that is life- or organ-threatening, use thromboplastin.

Arterial Disorders

Arteriovenous Malformations

- Usually occur in lower limbs and are associated with unilateral limb hypertrophy (hemihypertrophy).
- A hepatic arteriovenous malformation (AVM) in a newborn may produce congestive heart failure.
- Intestinal AVM may produce bleeding.
- Physical findings include increased warmth, swelling, and pulsating varicosities.
- Diagnose by Doppler ultrasound, angiography, or magnetic resonance imaging.
- Treat for complications, such as bony erosion, pain, and functional disability.
- Treatment may include surgical excision and angiographic embolization.

Visceral Aneurysms

- Visceral aneurysms, though rare, occur most commonly in the renal and splenic arteries.
- Treat by resection and reanastamosis if the aneurysm is larger than 2 cm.

Connective Tissue Disorders

Marfan Syndrome

- Physical findings include tall, thin body habitus, arachnodactyly, and lens dislocation.
- Symptoms include inguinal hernias, spontaneous pneumothorax, pectus carinatum, and aneurysms of the ascending aorta, which results from cystic medial necrosis that ruptures the intima and initiates aortic dissection (sudden aortic insufficiency is a common early manifestation of aneurysm).

Acquired Disorders

- Kawasaki disease: manifested by skin rash, erythema, edema of the hands and feet, arthritis, cervical adenopathy, and conjunctivitis and aneurysms of the coronary and peripheral arteries.

- Thrombi and emboli: occur in infants of diabetic mothers and manifest with dehydration and polycythemia, which may produce a state of hyperviscosity and result in thrombosis.
  - Umbilical artery catheters may be associated with aortic and renal artery thrombosis that leads to hypertension and heart failure.
  - Treat with heparin, hydration, and, in some cases, total parenteral nutrition.
- Occlusive syndromes
  - Intracranial and extracranial arteries (eg, sickle-cell disease, which is the most common cause of stroke in children).
  - Renal artery stenosis (resulting from fibromuscular dysplasia).
    - Symptoms include hypertension, producing headache, visual disturbance, and congestive heart failure.
    - This is the second most common cause of surgically correctable hypertension (coarctation is first).
    - Usually bilateral.
    - Diagnose using aortogram with renal angiography.
    - Treat with reconstruction using a hypogastric artery graft from the aorta to the distal renal artery.
      - Saphenous vein grafts are contraindicated because of the potential for aneurysmal dilatation when used in children.
      - Transaortic balloon dilatation may be effective if stenosis is in branches, but not if stenosis is at a renal orifice (eg, ostium).

Traumatic Vascular Injury

Due to the laxity of soft tissue, vascular injuries in children may be associated with greater blood loss from third spacing compared to adults; collateral blood flow is also more extensive in children because of the lack of atherosclerotic narrowing in their vessel lumens. The most commonly injured vessels are the brachial, superficial femoral, and popliteal arteries (Tables 19-1 and 19-2).

- General principles
  - Apply direct pressure to control bleeding.

Table 19-1. Arteries to Ligate Versus Arteries to Reconstruct

Arteries That May Routinely Be Ligated	Arteries That Should Be Reconstructed
Digital, radial, or ulnar (not both, preserve ulnar when possible)	Common/internal carotid
External carotid	Subclavian
Brachial (if distal to profunda and adequate signal is present at wrist)	Axillary
Subclavian branches	Brachial (if there is no Doppler signal at the wrist)
Internal iliac and profunda femoral arteries*	Common iliac
	External iliac
	Superficial femoral
	Popliteal
	Tibioperoneal trunk
	Celiac
	Aorta

*Preserve at least one tibial vessel. The posterior tibial artery is the most critical to repair, followed by the dorsalis pedis and the peroneal arteries, respectively.

  - Indications for mandatory surgical exploration include pulsatile bleeding, expanding hematoma, absence of distal pulses (cold or pale limbs), thrill, and bruit.
  - Findings that may permit close observation with serial Doppler ultrasound for 24 hours include history of hemorrhage at the scene, nonexpanding hematoma, diminished (but present) pulse, proximity injury, and nerve deficit.
- Equipment needed
  - Stethoscope.
  - Doppler ultrasound.
  - Argyle vascular shunts (Medtronic, Minneapolis, Minn; Fr sizes 8, 10, 12, 14).
  - Fogarty embolectomy balloon-tipped catheters (Edwards Lifesciences Corporation, Irvine, Calif; Fr sizes 2, 3, 4, 5).
  - Heparin (100 units/mL saline flush).
  - Heparin, unfractionated (for intravenous administration when there are no associated injuries to the head, chest, or abdomen).

Table 19-2. Veins to Ligate Versus Veins to Reconstruct

Veins That May Routinely Be Ligated	Veins That Should Be Reconstructed
Internal and external jugular	Popliteal for prevention of extremity venous hypertension and potential for compartment syndrome
Brachiocephalic	Common and external iliac, if time and patient condition permit
Left renal	Portal vein
Infrarenal inferior vena cava (to control damage)	Right renal vein
Internal iliac	
Tibialis	
Carotid	
Mesenteric	
Subclavian	

    - Prolene (Ethicon Inc, Somerville, NJ) suture material on vascular needles (3-0, 4-0, 6-0, 7-0).
    - Loupes.
    - Fine vascular instruments (bulldog clamps, Castroviejo scissors, DeBakey clamps, etc).
- Vascular examination
    - Vasospasm is common in children under 10 years of age. Warm the extremity and wait 30 to 45 minutes. If vasospasm does not improve, consider papaverine injection.
    - Check pulse.
    - Assess ankle brachial index (ABI); less than 0.9 or a difference between the lower extremities greater than 0.1 is abnormal.
    - Use Duplex ultrasound.
    - Perform on-table angiography.
        - Computed tomography angiography with 3-dimensional reconstruction may be useful to detect occult vascular injury and avoid conventional angiography.
        - Catheter-directed angiography is useful for localizing injuries with abnormal physical examinations (ABI < 0.9) or soft signs of injury; hard signs of injury (eg, expanding hematoma, pulselessness, bruit, or thrill) should be explored.

- To treat diminished inflow or outflow secondary to an embolic occlusion of vessel lumen, carefully perform an embolectomy with a small Fogarty catheter and continuously flush with heparinized (1 unit/mL) saline and papaverine (30–60 mg in 100 cc).
- Principles of performing a vascular anastomosis
  - It is essential to magnify the operative field by properly adjusted loupes or microscope.
  - A reversed segment of greater saphenous vein from an uninjured limb makes an ideal conduit, although small vessel size may contribute to technical challenges or necessitate a panel or spiral graft.
  - Alternate veins for interposition grafts are basilic, internal jugular, and internal iliac.
  - Avoid using prosthetic vascular material due to the associated risk of infection.
  - Blood vessels will grow with the patient, so an autogenous graft with an interrupted suture line is favored over prosthetic conduits of fixed diameter.
- A spatulated, primary end-to-end anastomosis has the best patency rate and can be performed when segmental loss is limited to less than 0.5 cm; a patch repair is an option when greater than 50% of the native wall is preserved to avoid a residual stenosis.
- Any anastamosis must be tension-free, have sufficient inflow and outflow, not leak, and provide adequate soft tissue coverage if it is to remain patent.
- Classic extremity fractures that contribute to vascular injury are those in the humerus (brachial artery), tibial plateau, and proximal tibia (tibioperoneal trunk). Bony fixation should precede vascular repair.
- A continuous Doppler assessment should always confirm the pulse examination; an ABI less than 0.9 is abnormal and should be investigated. C-arm and fluoroscopy units should be available for focal vascular visualization, but complete angiography is rarely necessary.
- Micropuncture needles with intrinsic guide wires are helpful for emergent arterial and venous access.

- Assess grafts for flow every 3 months for 2 years, then biannually for 3 years, and then annually for life.
- Intraluminal shunts (eg, Argyle) may be used as a temporizing measure to prevent tissue ischemia, with revision if the patient demonstrates symptoms of ischemia.
  - This maneuver may be limb-saving when a patient must be transferred to a higher echelon of care for definitive vascular repair.
  - It is **imperative** that the dressing clearly state in writing that a vascular shunt is in place and identify the vessel that is shunted, the size of the shunt, and the date and time it was placed and the name and contact information for the surgeon who performed the procedure. This information must be verbally communicated to the medical officer responsible for the patient during transport as well as to the receiving physician. **This point cannot be overemphasized.**
- Findings on a chest radiograph suspicious for associated injury to the thoracic aorta include
  - widened mediastinum,
  - apical "cap,"
  - fractures of the first or second ribs,
  - fracture of the scapula, and
  - rightward deviation of the trachea/endotracheal tube.
- Surgical artery exposure
  - Ascending aorta/arch: median sternotomy with or without cervical extension.
  - Descending aorta: left posterolateral thoracotomy at fourth intercostal space.
  - Subclavian artery
    - Left: left posterolateral thoracotomy at fourth intercostal space with "trap door" median sternotomy.
    - Right: median sternotomy with right cervical extension.
  - Common femoral: vertical groin incision, with extension cephalad into abdomen for proximal control if necessary.
  - Superficial femoral/popliteal: medial incision of leg posterior to sartorius, with extension through semitendinosus and semimembranosus into lower leg.
  - Tibial vessels: medial incision.

- Common technical pitfalls
  - Revascularization of an extremity after more than 4 to 6 hours of ischemia necessitates a fasciotomy. A two-incision fasciotomy of the leg must release all four compartments.
  - Inadvertent failure to reverse the interposed segment of peripheral vein.
  - Excessive graft length, resulting in kinking and graft thrombosis.
  - Inadequate graft length, resulting in anastomosis disruption due to excessive tension.
  - Failure to adequately cover the graft with viable soft tissue, leading to desiccation and disruption.
  - A break in sterile technique, resulting in graft infection.
  - Inadequate debridement may create an intimal flap, leading to occlusion.
  - Poor distal runoff, resulting in occlusion or vasospasm.
  - Inadequate immobilization of the associated bony injury, resulting in graft disruption.
  - Failure to prevent, recognize, or treat a compartment syndrome after revascularization, resulting in graft occlusion and tissue loss from ischemia.
- Postoperative management (all records should include time of observation and name of observer)
  - Frequently monitor distal pulses by palpitation and Doppler ultrasound.
  - Assess capillary filling, warmth, and sensation.
  - Monitor for hematoma formation.
  - Observe for compartment syndrome.

Chapter 20

Abdominal Wall, Peritoneum, and Diaphragm

Abnormalities of the abdominal wall, peritoneum, and diaphragm usually present in infancy.

Disorders of the Umbilicus

Umbilical Drainage

- Omphalitis is a life-threatening infection of the newborn abdominal wall around the umbilical stalk.
  - Etiology
    - Omphalitis may be caused by poor hygiene and care of the umbilical stalk after birth.
    - It is most commonly caused by *Staphylococcus aureus*.
    - *Clostridium perfringens* (purple wound) is rare, but is associated with high mortality.
  - Omphalitis may result in portal vein thrombosis, leading to portal hypertension and, eventually, to upper gastrointestinal bleeding (treated nonoperatively).
  - Treatment
    - Give broad-spectrum antibiotics to cover *Staphylococcus aureus*.
    - Surgically debride and excise umbilical vessels and necrotic soft tissue, if needed.
- Granulomas are collections of inflamed tissue.
  - Treat small granulomas with silver nitrate. Repeated applications over several weeks may be required.
  - Treat large granulomas by surgical excision (electrocautery).
- Polyps are vitelline duct remnants consisting of a small piece of intestinal mucosa.
  - They appear as glistening, cherry-red nodules in the base of the umbilicus. They are often mistaken for granulomas.

- Polyps are usually asymptomatic, but may cause local irritation because of persistent moisture.
- Treatment
  - Initially, try silver nitrate cauterization (rarely effective).
  - Surgically excise with the central core of the umbilicus for polyps that persist beyond 6 to 12 months.
- Persistence of vitelline duct structures include omphalomesenteric sinus, fistula, Meckel's diverticulum, cysts, and bands.

Urachal Sinus

- Urachal sinus is a cord-like, mucosal-lined structure extending from the dome of the bladder to the lower border of the umbilical ring.
- Symptoms include urinary fistula with urine drainage from the umbilicus.
- Urachal sinus is often associated with urinary tract anomalies, such as bladder outlet obstruction (eg, posterior urethral valves) and recurrent cystitis.
- Diagnose with ultrasound and voiding cystourethrogram.
- Treatment
  - A small fistula may close after 1 to 2 weeks of bladder decompression with a Foley catheter.
  - Excise the entire tract down to the bladder via an infraumbilical incision. Leave Foley catheter for 3 to 5 days following operation.

Urachal Cyst

- A urachal cyst may occur anywhere along the urachal tract, from the umbilicus to the bladder.
- Symptoms include enlarging suprapubic or infraumbilical mass, which may become infected, resulting in a urachal abscess (which may appear as an infection of the abdominal wall).
- Diagnose with ultrasound.
- Treat an infected cyst with antibiotics and abscess drainage, then excise the cyst via an infraumbilical incision after the acute inflammation has resolved. A cyst may resolve

spontaneously by 12 months of age if it is not infected. If it persists beyond that period, the cyst should be resected because of the potential for malignant degeneration.

Patent Omphalomesenteric Sinus

- Patent omphalomesenteric sinus may be caused by a persistent vitelline duct, usually at the site of a Meckel's diverticulum (located in the terminal ileum).
- Symptoms
  - Contents of the small bowel may drain through the umbilicus.
  - Obliterated cord may become fixed to the umbilicus and may be associated with a closed-loop intestinal obstruction.
- Diagnose with ultrasound or sinogram.
- Surgically excise via an infraumbilical excision, with closure of the ileal defect or segmental small bowel resection.

Umbilical Hernia

- Umbilical hernias are very common in infants and children before 5 years of age and often resolve when the rectus muscles develop. Unlike in adults, incarceration is rare in children.
- Surgical repair is needed for cases of incarceration, strangulation, or evisceration; for a herniation that is proboscis-like (repair at 2 years of age); and a fascial defect that persists beyond 3 to 4 years of age. Pain may indicate impending incarceration and should prompt repair regardless of age.
- Repair technique
  - Meticulously cleanse the periumbilical skin.
  - Give one dose of intravenous (IV) antibiotics to cover *Staphylococcus* within 1 hour of the surgical start time.
  - Perform infraumbilical incision and excise the sac, if possible.
  - Complete a transverse fascial closure using an interrupted, long-term absorbable suture (Vicryl, [Ethicon US, LLC, Somerville, New Jersey] or polydioxanone [PDS; Ethicon US, LLC, Somerville, New Jersey]). **Never use mesh!**
  - Attach dermal umbilical skin to the underlying fascia.

- Use a pressure dressing for 72 hours to prevent a hematoma.
- Nonsteroidal antiinflammatory drugs are usually sufficient for postoperative analgesia, especially if the wound was infiltrated with a local anesthetic.

Epigastric Hernia

- Epigastric hernias occur at the linea alba above the umbilicus.
- They usually result from a congenital fascial defect.
- An epigastric hernia manifests as a protrusion of preperitoneal fat that appears as a small, palpable, irreducible mass in the midline (usually supraumbilical, often multiple).
- Symptoms include pain and tenderness.
- Treat by operatively repairing via a transverse incision.

Spigelian Hernia

- A Spigelian hernia is located between the semilunar line and lateral border of the rectus sheath.
- It is prominent when the patient is crying and straining.
- The sac may contain omentum or bowel.
- Diagnosis is made by computed tomography scan or ultrasound.
- Treat with surgical repair.

Inguinal Disorders

Anatomy

- Processus vaginalis is a peritoneal diverticulum that extends through the internal inguinal ring. Failure to close may result in an indirect inguinal hernia. In an indirect hernia, a hernia sac is anterior and medial to the cord structures, lateral to the epigastric vessels.
- A communicating hydrocele occurs when intraperitoneal fluid has tracked down the patent processus vaginalis into the tunica vaginalis. In females, a hydrocele may occur along the round ligament (canal of Nuck), presenting as a bulge or mass in the labia majora.

Incidence of Inguinal Hernias

- Incidence is approximately 3% overall.
- Male-to-female ratio is about 10 to 1.
- Incidence on the right is approximately 50%, left approximately 25%, and bilateral approximately 15% because of the later descent of the right testis and delayed obliteration of the processus vaginalis.
- Incidence is increased in premature infants (approximately 20% incidence).
- Increased-risk patients include those with cystic fibrosis, chronic lung disease, connective tissue disease, and those on peritoneal dialysis or with a ventriculoperitoneal shunt.
- Treat with routine bilateral explorations.
- Direct and femoral hernias are rare in children.

Hydrocele

- Noncommunicating hydroceles usually resolve by 12 months of age; if not, they should be considered hernias and repaired.
- Diagnosis is made by transillumination or ultrasound. The hydrocele is usually absent upon waking, and most prominent once the child is ambulatory because gravity moves intraperitoneal fluid through the processus.
- If the hydrocele is present after 12 months of age, treat by ligating the patent processus vaginalis and excising the hydrocele. Aspiration is not recommended. If the processus is patent, the hydrocele will recur; if the hydrocele is encysted, it will resolve spontaneously.

Symptoms of Inguinal Disorders

- Indirect hernia is the most common sign of an inguinal disorder.
  - An indirect hernia manifests as a groin bulge that extends toward the top of the scrotum.
  - A palpable mass in a female in the labia majora usually represents an ovary (if the mass is bilateral, suspect testicular feminization syndrome; strangulation is rare).
  - Visibility is better during periods of increased intraabdominal pressure (eg, crying, stooling).

  - The spermatic cord thickens as it crosses pubic tubercle ("silk glove" sign).
  - Hernia sac is anteromedial to cord structures and lateral to the epigastric artery and vein.
- Direct hernia is rare in children. It may result from an injury to the floor of the inguinal canal during a previous hernia operation. It occurs medial to epigastric vessels.
- Hydrocele
  - Communicating: intermittent scrotal swelling.
  - Noncommunicating: remains the same size.
  - Ultrasound may be valuable in distinguishing a hydrocele from an inguinal hernia; transillumination is less specific.
  - Hydroceles usually resolve spontaneously by 2 years of age. If not, resection should be performed.

General Principles of Treatment

- Treatment for inguinal disorders is required in certain patients, including
  - Those with a hernia on physical examination or with a convincing history consistent with a hernia.
  - Patients who present with incarcerated hernias that can be reduced. These patients should be admitted and have semielective repair before discharge (waiting 24 hours from the time of reduction to operation permits edema to subside).
  - Premature infants with (usually indirect) hernias. These should be repaired prior to the child's discharge.
  - Patients with an undescended testicle at the time of hernia repair. Perform an orchiopexy at the same time.
- Infants less than 50 weeks old (corrected gestational age) who were premature should be admitted for overnight observation postoperatively to monitor for residual effects of anesthesia (apnea and bradycardia).
- Excise an appendix testis to prevent torsion.

Complications

- Incarceration occurs when sac contents (usually bowel) cannot be reduced nonoperatively. This is much more common with indirect hernias (Figure 20-1).



Figure 20-1. Inguinal hernia containing incarcerated intestine.

- Incarceration is most common in infants less than 1 year old.
- Symptoms include severe irritability, cramping abdominal pain, and vomiting.
- Physically, incarceration manifests as a firm, nontender mass in the groin.
- Pathology: decreased venous and lymph drainage increases edema and pressure. This leads to decreased arterial perfusion and eventual gangrene and necrosis, which presents as scrotal redness, edema, or a mass (strangulation).
- Treatment
  - Attempt reduction.
    - Sedate (using midazolam 0.05–0.1 mg/kg, or chloral hydrate).
    - Elevate the lower body.
    - Apply ice to the hernia sac.

        - If nonoperative reduction is successful, admit the patient for repair in 24 hours.
        - If nonoperative reduction is unsuccessful, perform immediate operative reduction via an inguinal incision.
        - If the patient's bowel is infarcted, perform a resection through the groin incision if possible; if not, perform a laparotomy.
        - Surgical exploration of the contralateral groin is controversial. The decision to proceed with surgery should be based on the patient's ability to obtain surgical care should a hernia occur, and the risk of testicular or vas deferens injury.
    - Complications of incarceration include
        - gonadal infarction,
        - intestinal obstruction, and
        - gangrenous bowel.
            - Physical appearance: erythematous scrotum.
            - Attempts at reduction are usually unsuccessful.
    - Recurrence
        - A direct hernia may occur at the repair site of a previous indirect hernia if there has been an intraoperative injury to the floor of the inguinal canal.
        - Excessively tight closure of the internal inguinal ring can result in recurrence.
            - Symptoms include tender, swollen testis.
            - Treatment consists of reexploration and inspection of the testis.

Abdominal Wall Defects

Gastroschisis

- "Gastroschisis" is Greek for belly cleft (Figure 20-2).
- Bowel is histologically normal, but thickened and shortened due to prolonged contact with amniotic fluid. These changes are reversible with time and after reduction into the abdominal cavity.
- The defect is almost always to the right of the umbilical cord (which is normally positioned) and separated from it by a skin bridge.



Figure 20-2. Gastroschisis.

- Midgut, stomach, and gonads are the most commonly herniated organs (liver rarely herniates in gastroschisis).
- There is no sac covering the herniated viscera.
- Malrotation is always present (in both gastroschisis and omphalocele).
- Associated anomalies are rare (except intestinal atresia).

Omphalocele

- In most cases, the bowel is covered by an intact membrane, from which the umbilical cord arises (ie, herniation into the base of the umbilical cord) so gastrointestinal tract function is usually normal; in a "ruptured" omphalocele, the membrane is not intact.
- Malrotation is present.
- The omphalocele often contains liver.

Incidence

- Gastroschisis-to-omphalocele ratio is 2–3:1.
- Both are associated with prematurity.

Anomalies

- Gastroschisis
  - Associated conditions include
    - undescended testicles (common),
    - atresias due to vascular compression in utero,
    - hypoperistalsis, and
    - necrotizing enterocolitis.
- Omphalocele
  - Sixty percent of patients with omphalocele have associated abnormalities (cardiac, vertebral, limb, and chromosomal [eg, trisomy 13, 18, or 21]).
  - Associated with Beckwith-Wiedemann syndrome, which can result in or be associated with
    - macroglossia, which may cause airway problems;
    - visceral hypertrophy (cardiomegaly, pancreatic β-cell hyperplasia that results in hypoglycemia);
    - Meckel's diverticulum, gastrointestinal tract duplications, and ambiguous genitalia; and
    - increased association of malignant tumors (Wilms', neuroblastoma, adrenal).
  - Prenatal ultrasound (greater than 13 weeks gestation) is usually accurate.
  - Vaginal delivery is not associated with more complications than cesarean delivery, with the exception of large omphaloceles.
  - Treatment
    - Insert an orogastric tube and place to low suction.
    - Use a "bowel bag" or plastic cling film to conserve body heat, minimize evaporative heat loss, and prevent traction or twisting of the mesenteric blood supply; this is the most important aspect of pretransport and preoperative preparation.
    - Antibiotics
      - Ampicillin (100 mg/kg/day)
      - Gentamicin (5–7 mg/kg/day)
    - IV fluids
      - 20 cc/kg Ringer's lactate or 5% albumin.
      - 150 to 175 cc/kg Ringer's lactate during the first 24 hours.

        - If not adequately hydrated, the child may become hypotensive on induction of anesthesia due to hypovolemia.
    - Vitamin K
        - Premature infant: 0.5 mg intramuscular.
        - Full-term infant: 1 mg intramuscular.
- Omphalocele and gastroschisis
    - Steps for primary closure
        - Excise the omphalocele sac (except if it is attached to the liver).
        - Inspect the umbilical cord and number of umbilical arteries (the presence of a single artery may be associated with an absent kidney).
        - Inspect the bowel for atresias or perforations (omphalocele), do not attempt to undo matted loops of bowel.
        - Manually stretch the abdominal wall.
        - In gastroschisis, if a larger opening is required to reduce the herniated viscera, open the fascia cephalad in the midline.
        - Manually extrude meconium from the colon after anal dilatation and saline irrigations (do not perform an enterotomy to evacuate meconium).
        - Do not excise a Meckel's diverticulum.
        - The liver must be reduced carefully to avoid torsion of the hepatic veins or occlusion of portal vein inflow that results in hemodynamic instability and injury to the capsule (omphalocele).
        - Close the fascial defect and skin.
    - Complications of an excessively tight closure include
        - Respiratory insufficiency secondary to excessive pressure on the diaphragm. Peak inspiratory pressure should be less than 35 cm H_2O after fascial closure; abdominal compartment pressure should be less than 15 cm.
        - Vena cava compression, resulting in decreased venous return.
        - Decreased renal vein flow, resulting in decreased glomerular filtration rate.

- Decreased mesenteric artery flow, resulting in bowel ischemia (an immediate primary repair in an infant with respiratory distress syndrome is contraindicated due to resultant high mortality).
- If there is any question about bowel viability, place a silo and perform a second look in 12 to 24 hours.

- Do not attempt definitive repair until chromosomal abnormalities and possible cardiac defects have been evaluated.
- Delayed primary closure
  - Sew silicon-plastic or Gore-Tex (WL Gore & Associates, Inc, Newark, Del) sheets to the edges of the fascia; a silicon-plastic bag (with an integrated spring to hold the base open) can also be used and does not require suturing.
  - Gradually reduce the silo over several days.
  - Remove the silo and perform primary fascial closure after about 7 days, or, in the case of a large omphalocele:
    - Allow the sac (which must be intact) to thicken and epithelialization to occur before applying escharotic or desiccating agents.
    - Use Acticoat (Smith & Nephew, London, England) dressing and change every 4 to 5 days.
    - Povidone-iodine may be associated with iodine absorption and suppression of thyroid-stimulating hormone.
    - 0.5% silver nitrate may be associated with hyponatremia.
    - Apply silver sulfadiazine twice a day for 2 weeks and perform primary skin closure in about 2 months.
    - Indications for applying escharotic agents include suspected chromosomal syndromes (eg, trisomy 13 or 18); severe, unstable cardiac defects (eg, hypoplastic left heart, hypoplastic aortic arch); and, in premature infants, hyaline membrane disease, primary pulmonary hypertension, and sepsis.

- Intestinal atresia
  - Conserve bowel when feasible.
  - Perform ileostomy.
  - Both gastroschisis and omphalocele are always associated with intestinal nonrotation (malrotation), which is typically benign and does not require treatment due to the low risk for volvulus.
  - Postoperative considerations
    - Provide ventilator support for 48 to 72 hours, pharmacological paralysis (using pancuronium bromide).
    - Provide total parenteral nutrition until full enteral feeds can be resumed, which may require weeks to months.
      - Normal intestinal absorption may be delayed for weeks.
      - Dysmotility problems may persist for weeks to months.
    - If gastrointestinal contrast studies show no evidence of obstruction, do not operate; operating will only create new adhesions.
    - Place a gastrostomy tube, continue total parenteral nutrition, administer physical therapy for sucking, give erythromycin to increase motility, and be patient.
    - Administer 5% albumin infusions, as needed.
    - Continue antibiotics until the silicon-plastic silo has been removed.
    - The patient may experience increased gastroesophageal reflux due to increased intraabdominal pressure; this rarely requires fundoplication.
  - After successful skin closure of a giant omphalocele, a ventral hernia repair may be associated with hemodynamic instability due to hepatic venous anatomy.
  - Long-term complications
    - Stricture may result in a small-bowel obstruction.
    - Ventral hernia.
    - Undescended testicles.
  - Survival depends on prematurity, size of the defect, and severity of associated anomalies.

Disorders of the Peritoneum and Peritoneal Cavity

Abdominal Compartment Syndrome

- Etiology: increased intraabdominal pressure due to an inflammatory process (eg, perforated appendix) or any space-occupying condition (eg, bleeding, edema) that increases the volume of the abdomen.
- Symptoms include
  - sepsis,
  - respiratory distress due to pressure on the diaphragm,
  - oliguria due to renal vein compression,
  - hypotension due to vena cava compression and decreased venous return,
  - vasomotor changes, and
  - acidosis due to hypoperfusion.
- Abdominal distension is an obvious physical manifestation.
- Diagnosis is made when intraabdominal pressure is greater than 20 cm H_2O, as determined by measuring bladder pressures.
- Treatment consists of assisted ventilation, IV fluid administration, addressing the underlying cause, and abdominal decompression using a silo or wound vacuum device.

Meconium Peritonitis

- Meconium peritonitis is frequently associated with cystic fibrosis as the etiology of obstruction.
- Types
  - Pseudocyst: meconium is contained by necrotic bowel and omentum; the cyst wall is lined with calcium.
  - Plastic: free perforation causes marked generalized inflammatory reaction and adhesions.
  - Generalized: prenatal perforation with continuing leak produces meconium ascites.
- Etiology
  - Intrauterine volvulus of meconium-filled loop of bowel leads to intestinal vascular compromise.
  - This results in bowel ischemia then atresia, which leads to obstruction and, finally, perforation.

  - Symptoms include polyhydramnios, abdominal distension, and bilious vomiting.
- Diagnosis
  - Prenatal ultrasound will show polyhydramnios, dilated bowel loops, or calcifications.
  - Abdominal radiograph shows dilated loops of intestine and intraabdominal calcifications (linear calcifications may line the processus vaginalis and scrotum).
- Treatment
  - For obstruction or pneumoperitoneum, perform laparotomy with conservative resection.
  - In asymptomatic cases, observe the patient closely.

Omental and Mesenteric Cysts

- Omental and mesenteric cysts usually result from lymphangiomas.
- Symptoms include pain, vomiting, and abdominal mass.
- Diagnose with computed tomography scan or ultrasound.
- Treat with excision.

Ascites

- Etiology
  - Urinary tract malformation (eg, ureteropelvic junction obstruction, posterior urethral valves) resulting in obstruction (most common etiology in the neonate).
  - Immune hydrops (Rh incompatibility, cardiac anomalies).
  - Pancreatitis.
  - Ovarian cyst or tumor.
  - Chyle due to lymphatic abnormality.
- Treat the underlying abnormality.

Peritoneal Adhesions

- Immediate postoperative bowel obstruction is usually due to small bowel intussusception.
- Diagnose via an upper gastrointestinal study with small-bowel follow through.
- Treat initially by placing a nasogastric tube, administering IV fluids and antibiotics, and performing a laparotomy with adhesion lysis for a complete obstruction.

Congenital Diaphragmatic Hernia

- Normal openings in the diaphragm occur at the aorta, vena cava, and esophagus.
- Late-onset diaphragmatic hernias are diagnosed with a chest radiograph in an asymptomatic patient.
- Symptoms include gastrointestinal obstruction and respiratory distress (eg, severe hypercarbia, hypoxia).
- Treat by repairing hernia.
- Differential diagnosis may be congenital cystic adenomatoid malformation or sequestration.
- Defects
  - Esophageal hiatus (Morgagni's hernia; stomach prolapses into the mediastinum).
  - Congenital posterolateral defect (Bochdalek hernia).
  - Anomalous attachment of diaphragm to sternum and ribs.
  - Epigastric omphalocele and retrosternal defect in the diaphragm and pericardium (Pentalogy of Cantrell), producing herniation within the pericardium.
  - Attenuation of the tendinous or muscular portion of the diaphragm produces eventration (usually secondary to phrenic nerve injury).
- Incidence
  - Associated with malrotation.
  - Occurs more frequently in females than males.
  - Occurs most often on the left (90%).
- Diagnosis
  - Prenatal diagnosis
    - Polyhydramnios (75% incidence).
    - Associated with major central nervous system, cardiac, and chromosomal abnormalities (eg, trisomy 13 and 18). Many of these cases end in stillbirth.
  - Postnatal diagnosis
    - View prenatal ultrasound.
    - A chest radiograph will show the tip of the nasogastric tube to be above the diaphragm, indicating herniation of the viscera into the chest and a mediastinum shift.
    - Babygram will show intestinal loops herniated into the chest (Figure 20-3).



Figure 20-3. Defect in the posterolateral aspect of the left hemidiaphragm with intestinal loops herniated into the left chest.

    - Rule out associated abnormalities (which occur in 15%–25% of cases) in the following.
        - Central nervous system: head, spine (meningomyelocele).
        - Heart (most common): patent ductus arteriosus, ventricular septal defect.
        - Kidneys.
        - Lung: sequestration (occurring most commonly in left lower lobe).
    - Rule out chromosomal (trisomy 13) and metabolic abnormalities.
- Pathophysiology
    - A herniated viscus becomes distended with air, displacing the mediastinum.
    - Increased pulmonary artery pressure and pulmonary vascular resistance result from decreased pulmonary artery branches and thickened muscularis of bronchioles.
    - A right-to-left shunt through a patent ductus arteriosus and the foramen ovale results in hypoxia, hypercarbia, and acidosis; these lead to increased pulmonary vasoconstriction.
    - Acidosis and hypercarbia lead to pulmonary vasodilation.
    - Alkalosis and hypocarbia lead to pulmonary vasoconstriction.
- Physical symptoms and appearance include respiratory distress (evident by grunting, flaring, retracting, and cyanosis), scaphoid abdomen, shifted heart sounds, decreased bowel sounds, tracheal deviation, and bilateral pulmonary hypoplasia (more severe on the side of herniation).
- Treatment
    - Support spontaneous respiration; provide sedation with paralysis only if necessary.
    - Perform endotracheal intubation (avoid bag-mask ventilation to prevent insufflation of air into the stomach and small bowel).
    - Insert Replogle nasogastric tube.
    - Ventilator settings
        - Peak inspiratory pressure less than 25 cm H_2O.

        - Positive end expiratory pressure less than 6 cm H_2O (to minimize barotrauma).
        - 100% oxygen.
        - Adjust rate and inspiratory-expiratory ratio to maximize partial pressure of oxygen (PaO_2), decrease partial pressure of carbon dioxide ($PaCO_2$).
        - Maintain pH greater than 7.20 (permissive hypercapnia).
    - Place an umbilical venous catheter, umbilical arterial catheter (postductal), or right radial arterial line (preductal). When placing an umbilical arterial catheter, ideal arterial blood gas levels should be as follows.
        - PaO_2 greater than 40 mmHg.
        - $PaCO_2$ less than 30.
        - pH greater than 7.5.
    - Administer sodium bicarbonate or trimethylamine drip.
    - Provide volume replacement (Ringer's lactate or 5% albumin).
    - Maintain mixed venous saturation (from right atrium) greater than 65%.
    - Administer dopamine or dobutamine, as needed.
    - Tolazoline enhances histamine release, but can result in hypotension and peptic ulcers.
    - Nitric oxide (an endothelium-derived relaxing factor), which decreases pulmonary vasoconstriction, may be helpful.
    - Perform surgical repair after pulmonary hypertension has resolved.
    - Appropriate pulmonary vasodilators to administer include prostaglandin E1 and E2; appropriate pulmonary vasoconstrictors include prostaglandin F, thromboxane A1 and B2, and leukotrienes.
- Surgical repair
    - Perform surgical repair when the patient is physiologically stable, not as an emergency measure.
    - A diaphragmatic hernia is not an indication for fetal surgery.
    - Administer general anesthesia (eg, pancuronium).
    - Make a subcostal abdominal incision for right-sided or left-sided defects or thoracoscopy. In patients with a delayed

presentation, there are often dense adhesions between the incarcerated abdominal viscera and the lung, and repair is best approached via a transthoracic incision (posterolateral incision through the seventh intercostal space).
    - Reduce herniated viscera by excising the hernia sac, which is present in 10% to 20% of patients and may be easily missed.
    - Primary repair
        - For a small defect, use nonabsorbable suture material and pledgets.
        - For large defects, use bioprosthetic or synthetic prosthesis.
    - Place a thoracostomy tube to underwater seal.
    - A purple-brown mass near or in the left lower lobe may represent a sequestration.
        - Blood is usually supplied from a branch of the abdominal aorta below the diaphragm.
        - Treatment consists of excision with repair of the diaphragm.
- Postoperative care
    - Administer IV fluids (dopamine or dobutamine may be added).
    - Anticipate pneumothorax.
- Results
    - Overall mortality is approximately 50% (unchanged for the past 20 years).
    - Prognosis is determined by the degree of hypoplasia.
    - Lung volumes approach equality on a ventilation/perfusion scan.
    - Residual volume and functional residual capacity are increased.
    - Vital capacity, forced expiratory volume, and minute ventilation volume are normal or slightly decreased.

Eventration of the Diaphragm

- The most common cause of diaphragm eventration is injury to the phrenic nerve from the neck stretching during birth or from iatrogenic operative trauma.
- Symptoms

- Inspiration leads to negative intrathoracic pressure, which causes herniation of the viscera into the ipsilateral chest.
- This leads to mediastinum shift to the contralateral side, which results in respiratory distress or pneumonia.
- Diaphragm eventration occurs more frequently in the left diaphragm than the right.

- Diagnosis
  - Chest radiograph will show diffuse elevation of the hemidiaphragm (eventration).
  - Fluoroscopy or ultrasound of the diaphragm shows an elevated diaphragm with paradoxical motion.
  - Differential diagnosis is a congenital diaphragmatic hernia with hernia sac.
- Treatment
  - Initially intubate with assisted ventilation.
  - Perform posterolateral, transthoracic (seventh intercostal space) plication using multiple rows of nonabsorbable suture, only if the patient is symptomatic (ie, ventilator support is required for longer than 2 weeks, the patient is in respiratory distress, and the patient cannot tolerate exercise).
  - Complications
    - Recurrence (10%–15% of cases).
    - Chest wall deformity if plication is excessively taut.

Chapter 21

Gastrointestinal Tract

Surgical conditions involving the pediatric gastrointestinal (GI) tract are common and may encompass an almost endless array of anatomic malformations and pathophysiology. Surgeons should always keep in mind that their ability to accurately diagnose and treat many of these conditions will depend greatly on available resources and equipment, as well as on their personal level of expertise and that of other critical members of the operative and postoperative care team (ie, anesthesiologists, nurses, and respiratory therapists). Surgeons practicing in an environment with limited resources should accept the fact that good intentions do not always guarantee patient benefit.

Esophageal Conditions

Tracheoesophageal Fistula and Esophageal Atresia

- Epidemiology and risk factors
  - Tracheoesophageal fistula (TEF) and esophageal atresia (EA) occur in 2.4 per 10,000 live births.
  - Associated risk factors include prematurity (52%), Down syndrome (10%–20%), duodenal atresia (10%), maternal diabetes, and prolonged exposure to oral contraceptives or thalidomide.
  - There is a higher incidence of TEF and EA in Caucasians, males, mother's first progeny, children of older mothers, and in those with a family history of EA.
- Prenatal findings
  - Typical findings are polyhydramnios and a lack of a stomach bubble on radiograph (pure atresia).
  - Sometimes these findings are absent and the diagnosis is made after birth.
- Symptoms include

- Copious salivation (drooling) and aspiration at the time of first feeding, which is usually glucose water.
- Choking, coughing, respiratory distress, and cyanosis.
- Aspiration of acidic gastric secretions, resulting in chemical pneumonia (the most common cause of death).
- Abdominal distention as the stomach fills with air passing through the TEF (if present).

- Diagnosis
  - In a newborn, a nasogastric (NG) tube cannot be passed into the stomach and curls in the blind upper esophageal pouch (if proximal and distal—"pure" EA). The most common form of TEF or EA is a proximal EA with a distal TEF (85% of cases).
  - The bowel gas pattern seen on a radiograph of the chest and abdomen will aid in diagnosis.
    - Patients with pure atresia or distal EA with proximal TEF will manifest a gasless abdomen.
    - A fistula between the trachea and esophagus appears as a gas-filled stomach and bowel.
  - A contrast swallow should be avoided unless the diagnosis cannot be established by other means.
- Initial treatment
  - Give nothing by mouth.
  - Pass an NG tube (Replogle or sump-type tube) and place to low continuous suction. The tube should be irrigated periodically, as it tends to become occluded with secretions.
  - Initially provide maintenance intravenous (IV) fluids and consider starting total parenteral nutrition (TPN).
  - Elevate the patient's head to minimize aspiration.
  - Administer antibiotics (ampicillin and gentamicin).
  - Evaluate for associated VACTERL (vertebral, anorectal, cardiac, TEF, renal, and radial limb) abnormalities.
    - Take plain radiographs to rule out vertebral and limb anomalies.
    - Perform an echocardiogram to define cardiac anatomy and physiology.
    - Perform a renal ultrasound to detect anomalies.
  - Operative repair is best performed at a tertiary medical facility with neonatal intensive care unit capabilities and a pediatric surgeon.

- Pure atresias without a fistula are considered to be "long-gap" and are treated initially with a gastrostomy tube and enteral support until growth is sufficient to approximate the ends of the esophagus (3–4 months). Certain long-gap atresias may require esophageal replacement if primary anastomosis is not feasible. Options for esophageal replacement include
  - gastric transposition,
  - gastric tube,
  - colonic interposition, and
  - jejunal interposition.

Corrosive Injury of the Esophagus

- Incidence and demographics
  - The leading cause of corrosive injury of the esophagus is accidental ingestion in children. It is more common in developing countries where warning labels are not widely used.
  - Accidental caustic ingestions in children less than 5 years old and suicide attempts in young adults over the age of 20 result in a bimodal distribution.
- Common injury-causing agents
  - Alkali agents
    - Strong liquid alkalis (hydroscopic) are the most common cause of corrosive injury to the esophagus due to liquefaction necrosis (solids are more difficult to swallow and are usually expectorated).
    - Potassium hydroxide and sodium hydroxide (eg, detergents, laundry powders, button batteries, drain cleaners) are associated with severe injury.
    - Sodium hypochlorite (bleach) and detergents seldom cause clinically significant injuries.
    - Ammonia (eg, glass cleaners, toilet bowl cleaners) may also cause injury.
    - Injury to the esophagus is much more common than injury to the stomach in alkali burns.
  - Acidic agents
    - Strong acids have an odor and bitter taste that can induce emesis and thus can be protective.

    - Rapid acid transit causes sparing of the esophagus, but injures the stomach by coagulation necrosis.
    - Hydrochloric acid (eg, pool cleaners, metal and bowl cleaners) and sulfuric acid (eg, drain cleaners, car batteries) also commonly cause injury.
    - Hydrofluoric acid (eg, antirust products) can cause calcium abnormalities.
- Symptoms of corrosive injury of the esophagus include
    - vomiting;
    - dysphagia;
    - drooling, inability to swallow saliva;
    - abdominal or upper abdominal pain; and
    - burns of the mouth or pharynx.
- Diagnosis and management
    - The first priority is to assess the airway with direct visualization of the oropharynx and fluid resuscitation. Significant edema may require intubation.
    - Attempt to identify the agent and degree of exposure.
    - Perform esophagogastroduodenoscopy using a flexible endoscope, with the patient under general anesthesia, within 12 to 24 hours of injury.
        - This is the most accurate means of identifying the extent and severity of the esophageal and gastric injury.
        - Injured areas appear as a whitish coagulum surrounded by an area of hyperemia.
        - The endoscope should be passed only up to (but not through) the level of injury.
        - Avoid instrumentation after 24 to 36 hours after injury.
        - Deep, circumferential burns have a high incidence of stricture.
    - Cine esophagram is an accurate means of assessing the extent of esophageal injury including motility, and may help predict later stricture formation.
    - Chest and abdominal radiographs may identify pneumoperitoneum, pneumomediastinum, or pleural effusions, which are findings of full-thickness injury to the stomach or esophagus.
- Treatment

- If the patient does not have mucosal injury, discharge and follow up in 3 to 4 weeks.
- If the patient has a minimum to moderate burn, administer antibiotics (ampicillin and gentamicin) and perform an esophagram within 48 hours.
- If motility is undisturbed:
  - Give clear liquids for 72 hours.
  - After 72 hours, advance to a regular diet.
  - Discontinue antibiotics on the 14th day.
  - Discharge the patient and follow up regularly over the next 3 to 4 weeks.
- In severe cases:
  - Advance a string at the time of esophagogastroduodenoscopy.
  - Place a gastrostomy tube.
  - Give antibiotics; steroids have no therapeutic value and should not be administered.
  - If the cine esophagram is normal, give nothing by mouth until the patient can swallow saliva, then give only clear liquids. Advance the patient to a regular diet. Stop antibiotics and repeat the contrast swallow. Discharge the patient if the swallow is normal on the 21st day.
  - If the cine esophagram is abnormal, give nothing by mouth until a gastrostomy tube can be used. On the 21st day, stop antibiotics and repeat a contrast swallow. If the swallow is normal, discharge the patient with monthly follow-up for 1 year. If a stricture is present, initiate esophageal dilatations.

- Long-term complications include stricture (treat with monthly dilatations for 1 y), achalasia, and squamous cell carcinoma (latency may be longer than 20 years).
- Severe cases may require esophageal replacement (see section under Esophageal Atresia).

Esophageal Perforation

- Esophageal perforation is usually iatrogenic (nasogatric tube, endoscope).
- Symptoms
  - Drooling, bloody mucus with oral suctioning.
  - Respiratory distress (in newborns and infants).

- Subcutaneous emphysema.
- Substernal chest pain.
- Septic shock.
- Pleural effusion.

- Diagnosis
  - Chest radiograph will show pneumothorax, pneumoperitoneum, pneumomediastinum, and pleural effusion.
  - Perform esophagram using water-soluble contrast.
- Treatment
  - For traumatic perforation of the cervical esophagus in a newborn, insert an NG tube and administer broad-spectrum antibiotics.
  - For perforation of the intrathoracic esophagus with symptoms of mediastinitis (fever, manifestations of sepsis, leukocytosis):
    - Perform a posterolateral thoracotomy at the sixth intercostal space (left side for low esophageal perforations, right side for midesophageal perforations).
    - Administer broad-spectrum antibiotics.
    - Perform primary repair of the esophagus if the perforation is more than 24 hours old (interpose pericardial, pleural, or strap muscle patch) and consider placing a gastrostomy tube.
    - Place a chest tube for mediastinal drainage.
  - For contained perforations of the intrathoracic esophagus without symptoms of mediastinitis, observation, TPN, and antibiotics alone are often sufficient.
  - For cervical perforations, drainage, antibiotics, and follow-up studies are required.
  - If the perforation is more than 24 hours old with marked contamination, treat as above and consider performing a cervical esophagostomy, gastrostomy, and mediastinal/pleural drainage.

Gastroesophageal Reflux

- Reflux is normal in infants until 10 to 15 months of age when children assume a more upright posture, ingest a more solid diet, and develop increased lower esophageal sphincter tone.
- Symptoms include

- Recurrent vomiting, failure to thrive, and dysphagia.
- Recurrent aspiration pneumonia, coughing, stridor, and laryngospasm.
- Asthma-like symptoms.
- Esophagitis (occult blood loss causing iron-deficient anemia; may result in eventual stricture).
- Apnea, sudden infant death syndrome, and retrosternal burning (older children).
- Sandifer syndrome (voluntary contortions of the head, neck, and trunk associated with reflux esophagitis, producing iron-deficiency anemia).

- Diagnosis
  - Obtain a cine esophagram, contrast swallow, and upper gastrointestinal (UGI) series.
  - Perform esophagoscopy with biopsies (to diagnose esophagitis and Barrett's esophagus).
- Nonsurgical treatment (80% success rate)
  - Thicken feedings.
  - Position patient upright during and after feeds.
  - Administer oral erythromycin, a prokinetic (2–3 mg/kg/dose before meals), to assist with gastric emptying.
  - Give an antacid or H2-blockers (eg, ranitidine) to decrease acidity, or proton pump inhibitors (eg, omeprazole).
  - Give frequent, small-volume feeds or continuous tube feedings.
- Surgical treatment
  - Nissen fundoplication (360-degree wrap).
    - Indicated for
      - Esophageal stricture (especially if it occurs following a TEF repair with gastroesophageal reflux disease, and does not respond to serial dilatations).
      - Severe esophagitis (especially with secondary anemia).
      - Barrett's metaplasia (replacement of the normal stratified squamous epithelium lining of the esophagus by simple columnar epithelium resulting from chronic irritation secondary to gastroesophageal reflux).
      - Recurrent aspiration pneumonia.
      - Medical management failure.

        - Repeated vomiting with failure to thrive.
        - Severe apneic spells.
    - Postoperative complications include
        - wrap disruption resulting in recurrent symptoms,
        - excessively tight wrap resulting in dysphagia (this usually responds to dilation),
        - slippage of the wrap onto the stomach, and
        - hiatal hernia with displacement of the wrap into the mediastinum.

Esophageal Strictures

- Etiology includes reflux esophagitis, corrosive ingestion, and anastomotic scarring (may be aggravated by gastroesophageal reflux).
- Treatment consists of
    - serial dilatations,
    - antireflux procedure (if strictures are due to reflux esophagitis),
    - local resection (if stricture is short and circular), and
    - esophageal replacement (not a procedure performed in a resource-limited environment).
- Types of dilators include
    - Tucker (passed over a string);
    - Hurst, Maloney (mercury-weighted);
    - Jackson; and
    - pneumatic balloon.

Stomach and Duodenum

Infantile Hypertrophic Pyloric Stenosis

- Infantile hypertrophic pyloric stenosis (HPS) occurs in 2 to 4 per 1,000 births.
- Etiology is multifactorial with proven X-linked factor.
- Male-to-female ratio is 4 to 1 (most common in firstborn males). HPS occurs much more frequently in Caucasians than African Americans.
- HPS usually occurs at 2 to 6 weeks of age.
- Symptoms include
    - nonbilious projectile vomiting,

- ravenous appetite shortly after an episode of emesis, and
- blood-tinged emesis (which may be due to gastric or esophageal irritation).

- Physical examination
  - Visible peristaltic waves (left to right) are apparent during a test feed of glucose water.
  - A palpable olive (hypertrophied pyloric musculature) above and to the right of the umbilicus is palpable in 80% of cases if the child is not crying.
  - Signs of dehydration (sunken fontanelle, dry mucous membranes and lack of tears during crying, lack of wet diapers) are apparent if there is significant loss of intravascular volume due to prolonged episodes of emesis.
- Diagnosis
  - Diagnosis can be made by physical examination findings, as described above. If physical examination is doubtful, ultrasound is diagnostic in almost all cases.
  - HPS ultrasound criteria for pyloric stenosis
    - Diameter of pylorus greater than 14 mm.
    - Pyloric muscular thickness greater than 3 mm.
    - Thickened pyloric length greater than 16 mm.
  - A contrast UGI series should be performed only if the physical examination and ultrasound are not diagnostic. A "string sign" shows a thickened, narrow pyloric canal.
- Laboratory tests
  - Typically, the patient's electrolytes demonstrate a hypochloremic, hypokalemic metabolic alkalosis.
  - Hypokalemia enhances the secretion of hydrogen in urine, resulting in a paradoxical aciduria.
  - Increased bilirubin (indirect) is due to decreased glucuronyl transferase activity and may result in jaundice.
- Treatment
  - Correct fluid, electrolyte, and acid-base abnormalities using crystalloid boluses of 20 cc/kg of normal saline, then D_5 ½ normal saline plus potassium chloride (2–4 mEq/kg after patient urinates) at 1.5 times the maintenance volumes.
  - Resuscitation is adequate when the patient achieves a urine output of about 2 cc/kg/h, electrolytes are normal, and serum bicarbonate is less than 28 mEq/L (patients with

uncorrected metabolic alkalosis are at risk for dysrhythmias and apnea from general anesthesia) and chloride greater than 95 mEq/L.
  - An anesthesiologist should aspirate the patient's stomach before inducing anesthesia to decrease the risk of aspiration on intubation.
  - Ramstedt pyloromyotomy
    - Surgical approaches include transverse right upper quadrant incision, periumbilical incision, and laparoscopic pyloromyotomy.
    - A longitudinal incision is then made through the hypertrophied muscle to relieve the constriction while avoiding mucosal perforation.
- Postoperative feeding can be as needed after 4 hours postoperatively, or feedings may be gradually increased.
  - Initiate small-volume oral feedings of glucose and water at 4 to 6 hours following operation. For example, give
    - 15 cc oral electrolyte solution every 2 hours × 3, then
    - 30 cc oral electrolyte solution every 2 hours × 3, then
    - 30 cc full-strength formula or breast milk every 2 hours × 3, then
    - 60 cc full-strength formula or breast milk every 3 hours × 3, then
    - 90 cc full-strength formula or breast milk every 4 hours.
  - If vomiting occurs, wait 2 hours and retry the last volume tolerated.
- Treating complications
  - Mucosal perforation
    - Close the perforation in two layers using a polyglactin (absorbable, synthetic, braided) suture over an omental patch.
    - Perform a second myotomy at a site 180 degrees from the first site.
    - Give nothing by mouth and maintain an NG tube on suction for 24 hours before starting feeds. Consider obtaining a UGI study prior to reinitiating feedings.
  - Vomiting is usually secondary to gastritis or reflux and resolves in 1 to 2 days in almost all cases.
  - In the case of wound infection, prescribe antibiotics. Open the wound if an abscess is present.

- Bleeding may indicate the need for reexploration.
- Consider the presence of an incomplete myotomy only if vomiting continues for more than 5 to 10 days postoperatively, is forceful, or follows every feeding. Upon reexploration, redo the myotomy at a site 180 degrees from the original site.
- Arrhythmias and apnea are associated with general anesthesia in patients with uncorrected metabolic alkalosis (ie, serum bicarbonate less than 28 mEq/L); monitor pulse oximetry and apnea postoperatively.

Gastric Antral Web

- Pathology: submucosal web in the distal antrum is covered by gastric mucosa (no muscular layer present).
- Produces incomplete obstruction with an insidious delay in symptoms.
- Symptoms include postprandial, nonbilious vomiting, failure to thrive, and epigastric pain.
- Diagnosis (similar to duodenal atresia with a web)
  - A UGI contrast study will demonstrate a small amount of contrast passing through a ring of tissue in the distal stomach.
  - Upper endoscopy may be required if UGI is equivocal.
- Treatment consists of dilatation or endoscopic incision.
- Surgical correction
  - Perform a longitudinal gastrotomy incision over the site.
  - Excise a portion of the web.
  - Close the gastrotomy transversely.

Gastric Perforation

- Neonatal
  - Gastric perforation is more common in males, with incidence of 1 in 3,000 live births. Causes include ischemic insult from perinatal stress, gastric overinflation, and damage by an NG tube.
  - Symptoms include poor feeding, abdominal distention, and lethargy.
  - Other signs include tachycardia, lethargy, poor perfusion, tachypnea, hypotension, and peritonitis.

- Abdominal radiograph will show massive pneumoperitoneum and elevated diaphragms.
- Gastric perforation usually occurs on the greater curvature.
- Treatment
  - Give nothing by mouth.
  - Carefully place an orogastric tube.
  - Provide fluid resuscitation.
  - Administer broad-spectrum antibiotics.
  - Surgical treatment consists of transverse abdominal incision to identify the perforation, two-layer closure, and gastrostomy.

- Posttraumatic (eg, secondary to an NG tube or postoperative endoscopy)
  - Diagnose using UGI study with water-soluble contrast.
  - Treatment
    - Provide IV fluid resuscitation (20 cc/kg bolus Ringer's lactate).
    - Place an NG tube under fluoroscopic guidance.
    - Administer antibiotics (ampicillin plus gentamicin).
    - Perform a two-layer operative closure.
    - Perform a gastroduodenostomy (Billroth I operation) if the distal stomach is necrotic.

Bezoars

- Types
  - Trichobezoar (hair; usually seen in those with behavior disorders or in intellectually disabled children).
  - Phytobezoar (undigested vegetable fibers).
  - Lactobezoar (milk; caused by improper milk preparation, as with powdered formulas or concentrated milk requiring reconstitution or dilution).
- Symptoms include nonbilious vomiting, dehydration, and failure to thrive.
- A palpable epigastric mass may be evident on physical examination.
- Diagnosis is made by UGI series or endoscopy.
- Treatment consists of gastrotomy and surgical removal if the patient is symptomatic (symptoms of gastric outlet obstruction) and endoscopic removal is not possible.

Duodenal Obstruction

- Etiology
  - Duodenal atresia or web.
  - Annular pancreas.
  - Preduodenal portal vein.
- Anomalies associated with duodenal atresia include
  - Down syndrome (30%);
  - GI abnormalities, including annular pancreas, malrotation, biliary anomalies, and anterior portal vein; and
  - anomalies involving the cardiac, renal, and central nervous systems.
- Symptoms
  - Prenatal ultrasound may demonstrate polyhydramnios with dilated, fluid-filled stomach.
  - Bilious vomiting occurs after starting feeds, although 15% of cases have the obstruction proximal to the ampulla of Vater and vomiting may be nonbilious.
  - Infants have usually passed meconium by 24 hours of age.
- Diagnose using plain abdominal radiographs, which characteristically show a "double bubble" sign (representing air in the stomach and duodenum), with the absence of gas distally in the GI tract.
- Treatment
  - Preoperative preparation
    - Place an NG tube to suction to decompress the stomach and duodenum.
    - Provide IV fluid resuscitation (10–20 mL/kg of crystalloid or 5% albumin as a bolus, then maintenance). Urine output should be about 2 mL/kg/h.
    - Administer antibiotics (eg, ampicillin and gentamicin).
    - Perform echocardiogram to rule out congenital cardiac anomalies.
  - Operation
    - Emergency operative correction should be performed after fluid resuscitation and evaluation for possible cardiac abnormalities.
    - Malrotation discovered at the time of abdominal exploration for an intestinal atresia must be corrected.

- Perform a transverse, right supraumbilical incision, extending to the midline.
- If a "windsock web" is present,
  - Pass a Foley catheter (about size 8 Fr) through the length of the duodenum into the proximal jejunum and slowly withdraw.
  - Perform duodenotomy along the lateral aspect to avoid injury to the ampulla of Vater, which is located medially.
  - Excise the web. The medial portion may be left in place.

- In the case of duodenal atresia and annular pancreas,
  - "Kocherize" the duodenum.
  - Perform a duodenoduodenostomy (one layer, diamond-type anastomosis) if possible, or duodenojejunostomy (often required for annular pancreas). Never perform a duodenogastrostomy, which carries a risk of marginal ulceration.
  - If the proximal duodenum is significantly dilated, consider suture plication (interrupted Lembert sutures) or stapled tapering duodenoplasty (using an endostapler) on the antimesenteric side.
    - Place a transanastomatic nasojejunal tube to initiate early feedings.
    - Place an orogastric tube for gastric decompression until bowel function returns.
  - Return to normal bowel function is frequently delayed; consider using a central venous catheter for TPN.

Small Intestine

Malrotation With or Without Volvulus

- The ligament of Treitz extends from the left side near the second lumbar vertebrae to the sacroiliac joint in the right lower quadrant.
- Failure of mesenteric fixation during fetal development permits the midgut to rotate the last 90 degrees counterclockwise around the narrow mesenteric pedicle, containing its entire blood supply (superior mesenteric artery and superior mesenteric vein).

- The risk of volvulus in patients with malrotation does not decrease with age and should probably be surgically corrected, even in asymptomatic patients.
- Symptoms of midgut volvulus include
  - bilious vomiting (always rule out malrotation with volvulus and duodenal atresia in a newborn with bilious vomiting);
  - possible abdominal distention;
  - painful, tender abdomen;
  - hematemesis, hematochezia;
  - acutely ill appearance;
  - sepsis; and
  - shock (hypoperfusion state).
- Diagnosing midgut volvulus
  - Plain abdominal radiographs will show dilated stomach (double bubble) and gasless abdomen, but a normal film does not rule out malrotation.
  - Ultrasound may be used to determine the relative positions of the superior mesenteric artery and superior mesenteric vein.
  - UGI series shows the lack of a normal C loop of the duodenum and the ligament of Treitz lying to the right of the spine, entire opacified small bowel on the right side, and duodenal obstruction with the proximal duodenum appearing as a corkscrew at the obstruction point (if volvulus is present).
- Treating midgut volvulus
  - Midgut volvulus is a surgical emergency.
  - Perform a right transverse upper-abdominal incision.
  - Eviscerate and inspect the entire small bowel for areas of atresia or perforation.
  - Reduce a volvulus by counterclockwise rotation of the midgut.
  - Divide duodenal-colonic (Ladd's) bands, which extend from the cecum across the first and second portions of the duodenum to the retroperitoneum at the right gutter.
  - Widen the mesentery (this is the most important step to prevent recurrence).
  - Separate the duodenum from the cecum and place the cecum in the left lower quadrant; position the duodenum

and the proximal jejunum in the right lower quadrant and the ascending colon in the left upper quadrant.
    - Perform an appendectomy (the new, nonanatomical location of the cecum and appendix may delay a diagnosis of acute appendicitis later in life).
- Treating ischemic or necrotic small bowel
    - If a short segment is necrotic but the remainder is normal, perform a conservative resection and primary anastomosis.
    - If a short segment is necrotic but the remainder is of questionable viability, perform conservative resection with stoma formation. If the entire bowel from the proximal jejunum to the mid-transverse colon is necrotic, close the abdomen without resection and initiate palliative care.
    - Consider reexploration of the abdomen in 12 to 24 hours if large portions of the intestine or stomas appear ischemic.

Intestinal Atresias

- Intestinal atresias are the most common cause of congenital intestinal obstruction in newborns.
- They are caused by lack of recanalization of the bowel (for duodenal atresia) or by fetal intestinal infarction secondary to prenatal mesenteric infarction (jejunal or ileal atresias).
- Small-intestinal atresia most commonly occurs at the distal ileum. Diagnose by obtaining a UGI series with small-bowel follow-through.
- Colonic atresia represents only 5% of intestinal atresias, most commonly occurring at the level of the transverse colon.
- Diagnose by contrast enema. May be associated with Hirschsprung's disease.
- Prenatal ultrasound usually reveals polyhydramnios (more than 2,000 mL total amniotic fluid volume).
- Postnatal diagnosis
    - Early, bilious vomiting is associated with duodenal and proximal jejunal obstruction. Delayed (hours to days) vomiting is associated with distal intestinal obstruction.
    - Failure to pass meconium in the first 24 to 48 hours of life may indicate an atresia, but **passage of meconium does not exclude atresia.**

- Presence or absence of abdominal distention depends on the level of the obstruction.
- Jaundice (increased indirect bilirubin) may be associated with an atresia. β-glucuronidase in the intestinal mucosa deconjugates direct bilirubin and enhances enterohepatic recirculation of bilirubin in the presence of a bowel obstruction.

- Radiographs
  - Obtain plain films.
  - Double-bubble sign is associated with duodenal obstruction (atresia, annular pancreas).
  - Triple-bubble sign shows air in the stomach, duodenum, and bowel proximal to the area of small intestinal atresia.
  - Use limited UGI series to rule out malrotation or volvulus.
  - Paucity of gas may be present in the postatretic bowel.
  - Contrast enema may show the presence of a microcolon and dilated, air-filled proximal bowel, and may assist in the diagnosis of other causes of intestinal obstruction (eg, Hirschsprung's disease, meconium ileus).
- Treatment
  - Preoperative
    - Place an NG tube for decompression of the UGI tract.
    - Administer IV fluids.
    - Administer broad-spectrum antibiotics.
    - Rule out associated anomalies and cystic fibrosis.
  - Perform operative treatment for duodenal atresia (see Duodenal Obstruction), small bowel atresia, or colonic atresia.
  - Operative treatment of small bowel atresia
    - Inspect the entire small bowel for areas of atresia or stenosis.
    - Flush saline into the distal bowel to rule out additional areas of atresia or stenosis proximally and distally.
    - Resect the dilated proximal bulbous tip to avoid postoperative functional obstruction.
    - Perform primary end-to-end oblique anastomosis (a stapled, antimesenteric tapering duodenoplasty [duodenal atresia] or enteroplasty [small bowel] of the dilated proximal bowel is recommended to minimize the length of bowel resected).

        - Preserve the distal ileum and ileocecal valve, if possible, to prevent vitamin B12 and fat malabsorption. If primary anastomosis is not possible (eg, in premature infants or in the case of peritonitis), perform an ileostomy with exteriorization of one or both limbs.
    - In the case of colonic atresia, perform a primary anastomosis if possible, but consider Hirschsprung's disease (which may require temporary diversion).
    - Postoperative
        - Place an NG tube to low continuous suction.
        - Parenteral nutrition may be required due of the high incidence of prolonged postoperative ileus (sometimes persisting for several weeks).
        - Use elemental formulas (Nutramigen or Pregestimil [Mead Johnson Nutrition, Glenview, Ill]) and iron supplementation.
- Immediate and long-term complications include the following.
    - Sepsis resulting from an anastomotic leak.
    - Functional obstruction from megaduodenum (may be treated with reoperation with resection, plication, or tapering enteroplasty).
    - Duodenogastric reflux and esophagitis (treated medically).
    - Mechanical obstruction resulting from stenosis, adhesions, or internal hernia.
    - Short gut syndrome due to extensive intestinal resection.
- Mortality is usually associated with the presence of complex congenital heart disease (especially Down syndrome with endocardial cushion defect).

Meckel's Diverticulum

- Meckel's diverticulum occurs on the antimesenteric border of the distal ileum. It is often referred to as a "disease of twos," because it
    - is 2 inches long,
    - occurs 2 feet from the ileocecal valve,
    - is usually symptomatic by 2 years of age,
    - affects 2% of the population,
    - involves two potential types of heterotopic mucosa (gastric is more common than pancreatic),

  - occurs as a 2-to-1 ratio in males to females, and
  - involves two blood supplies (mesenteric and vitelline arteries).
- Symptoms
  - The most common presentation (40%–50%) in pediatric patients (< 5 years old) is sudden, painless, lower GI bleeding, which may be life threatening.
  - Symptoms are secondary to peptic ulceration in the adjacent ileal mucosa.
  - Occult bleeding (black, tarry stools resulting in anemia).
  - Meckel's diverticulum is the most common cause of massive rectal bleeding in pediatric patients (esophageal varices secondary to a history of omphalitis is the most common cause of massive hematemesis in this age group, and can be managed conservatively in almost all cases).
  - Meckel's diverticulitis pain is indistinguishable from that caused by acute appendicitis. It may cause an intestinal obstruction by acting as a lead point for intussusception or ileal volvulus around a fixation point to the umbilicus.
- Littré hernia is a Meckel's diverticulum trapped in an incarcerated umbilical or inguinal hernia.
- In a resource-limited environment, diagnose using ultrasound, especially if the presentation is intussusception ("donut or target sign"), or use computed tomography (CT) scan with oral contrast. Meckel's scan (technectium-99m pertechnetate isotope scan) will not be available in a deployed setting.
- Complications
  - Hemorrhage is the most common complication in children.
  - Obstruction is the most common complication in adults. Fibrous bands forming an attachment from the diverticulum to the abdominal wall may act as a lead point for ileocolic intussusception.
  - Perforation.
  - Localized ileal volvulus.
- Treat symptomatic cases by surgical excision (treatment of asymptomatic cases is controversial, but most pediatric surgeons feel that incidental diverticulectomy is not indicated).
  - If a narrow base is present, perform a wedge resection with transverse closure or stapled closure at the base.

- If a wide base is present or there is significant inflammation in the adjacent intestine, perform a segmental resection with end-to-end ileoileostomy.
- If manual intussusception reduction is not possible, perform a segmental resection.

Necrotizing Enterocolitis

- Necrotizing enterocolitis is the most common surgical emergency in neonates (infants less than 30 days old). Premature infants account for 90% of cases, but 10% occur in full-term newborns.
- Necrotizing enterocolitis usually occurs after the tenth day of life when coliform bacteria colonize the GI tract, but may occur at any time during the neonatal period.
- The most commonly affected sites are the terminal ileum and right colon (a "watershed" area).
- The most common pathology is ischemic necrosis of the superficial mucosa.
- Microthrombi occur secondary to platelet aggregation throughout the mesentery.
- Necrotizing enterocolitis is characterized by "skip areas" of involvement.
- Pneumatosis intestinalis is a pathognomic finding on abdominal imaging and is a manifestation of gas produced by bacteria within the intestinal wall.
- Radiographic findings
  - Plain abdominal films demonstrate intramural bowel gas.
  - Hydrogen gas (from *Escherichia coli*) will be evident by the presence of pneumatosis intestinalis.
  - Air in the portal venous system (associated with septic pylephlebitis) is a poor prognostic sign (however, these findings alone are not indications for operative intervention and are reversible with medical management).
  - Pneumoperitoneum may be present (secondary to GI perforation).
  - Static intestinal loops (persistent loops of adynamic or edematous bowel) are often seen on serial abdominal radiographs.
  - The earliest, most common radiographic finding is distention of multiple bowel loops.

- Bowel gas is diminished.
- Ascites is a grave sign.
- Abdominal wall ecchymosis is frequently indicative of underlying necrotic bowel and peritonitis.

- Physical examination
  - The patient's initial symptom will often be feeding intolerance (high feeding residuals), but some infants may have never been fed.
  - Abdominal distention is the most common sign.
  - Lethargy, bilious vomiting, rectal bleeding (usually as guaiac-positive stools), coagulopathy (especially thrombocytopenia), tachycardia or bradycardia, apnea, edema and erythema of the abdominal wall, and thermal lability are also common signs and symptoms.
- Laboratory studies
  - Thrombocytopenia (secondary to microvascular plugging and binding to gram-negative endotoxin) is the most relevant laboratory finding and may indicate disease progression with serial labs. It also may suggest fungal infection.
  - Leukopenia may be evident.
  - Laboratory studies may also show metabolic or lactic acidosis (pH less than 7.2, with an anion gap), especially with decreased serum sodium.
- Medical treatment
  - Give nothing by mouth.
  - Provide NG or orogastric tube decompression of the UGI tract.
  - Give IV (not enteral) antibiotics (ampicillin, gentamicin, and vancomycin or cefotaxime) for at least 10 days to cover *E coli, Klebsiella, Enterobacter*, *Pseudomonas*, and *Clostridium difficile*.
  - Maintain long-term central venous access and parenteral nutrition.
  - Take serial abdominal radiographs every 6 to 8 hours to screen for pneumoperitoneum.
- Surgical treatment
  - **Pneumoperitoneum is an absolute indication for surgical intervention**.

- Relative indications for peritoneal drainage or laparotomy include
  - deterioration on aggressive medical management (increasing acidosis, decreasing platelets);
  - positive peritoneal aspirate (brown color, positive Gram stain), which suggests the presence of gangrenous or perforated bowel;
  - palpable abdominal mass;
  - progressive peritonitis (edema or erythema of the abdominal wall);
  - intestinal obstruction;
  - fixed, dilated loops of intestine (unchanged after 24 h) on serial abdominal radiographs; and
  - portal vein gas (pylephlebitis).
- Operative technique
  - Make a right, transverse, supraumbilical incision.
  - Perform conservative resection of **only frankly gangrenous bowel** to prevent short-bowel syndrome.
  - Preserve the ileocecal valve, if possible.
  - Perform a second-look laparotomy at 24 to 48 hours to assess marginally viable bowel.
  - Administer broad-spectrum antibiotics and TPN postoperatively.
  - In very small, ill, premature infants, consider a peritoneal drainage procedure using a ¼-inch Penrose drain placed percutaneously under local anesthesia. This may be an effective temporizing (or definitive) therapeutic measure in an unstable, high-risk, premature infant with peritonitis, respiratory failure, or shock.
  - If resection of multiple necrotic segments is necessary, perform a proximal stoma and multiple primary anastomoses of the distal, defunctionalized bowel.

- Postoperative complications
  - The most common complication after surgery is stricture due to cicatricial healing of the injured mucosa, which may also be seen several weeks following successful medical management.
    - Stricture often presents weeks to months later as a bowel obstruction.

    - Diagnose by contrast enema.
    - Treat by performing a segmental resection and primary anastomosis.
  - Short-bowel syndrome, resulting from extensive bowel resection, is another potential complication.
    - Prevent short-bowel syndrome by performing conservative resection and second-look operations when the viability of the bowel at the initial operation is in question.
    - Treatment consists of TPN, elemental enteral formulas as tolerated, and prevention of central venous line infections.
  - Malabsorption (usually reversible) may result from extensive mucosal injury.
  - Survivors of severe necrotizing enterocolitis remain at high risk for growth and developmental delay.

Intussusception

- Intussusception occurs in 2 to 4 per 1,000 live births, predominantly in males.
- Idiopathic intussusception, seen in otherwise healthy children 6 to 24 months old, is usually due to hypertrophy of Peyer's patches in the terminal ileum from an antecedent viral infection (eg, rotavirus, reovirus, or echovirus); seasonal incidence (midwinter and early summer) corresponds with upper respiratory infections and GI viral disease.
- Pathological lead points are present in only 5% of children with intussusception, but with increased frequency in children older than 4 years of age. They may be caused by
  - Meckel's diverticulum (most common),
  - polyps (juvenile, hamartoma),
  - malignant tumors (eg, lymphoma, lymphosarcoma),
  - Peutz-Jeghers syndrome,
  - intestinal duplications,
  - hemangioma,
  - appendix,
  - cystic fibrosis (due to inspissated feces in the terminal ileum), or

  - Henoch-Schönlein purpura (hamartomas in the intestinal wall act as lead points for ileal-ileal intussusception).
- The most common site for intussusception in the pediatric age group is ileocolic; however, when associated with postoperative abdominal and thoracic operations, the most common site is ileal-ileal.
- Pathophysiology
  - Proximal portion of bowel (intussusceptum) is drawn into the distal loop (intussuscipiens) by peristaltic activity.
  - Mesentery of the proximal bowel is compressed and strangulated, leading to venous obstruction resulting in edema of the bowel wall. This leads to obstruction of arterial inflow, gangrene, and, potentially, to perforation and peritonitis.
- Symptoms
  - Intussusception is characteristically seen in an otherwise healthy child.
  - Patient will have paroxysms of abdominal cramping (usually lasting 10–15 minutes) and intermittent vomiting (70% of cases), screaming, and drawing of legs up to the abdomen.
  - Patient will have dark red (bloody) mucoid ("red currant jelly") stools.
  - An elongated (sausage-shaped) mass in the right upper quadrant may be present.
  - Symptoms include tachycardia, fever, and hypotension (if perforated), as well as absence of bowel in the right lower quadrant (Dance sign).
- Radiographic tests
  - Take flat and upright abdominal films. A cecal gas shadow may be absent in the right iliac fossa, and small bowel obstruction may be evident (air–fluid levels may be present on upright abdominal radiograph).
  - Ultrasound may show a "target sign," most often in the right lower abdomen.
  - Air enema or contrast enema will demonstrate a coiled-spring appearance of the lead point, which is diagnostic and may result in therapeutic reduction.
- Treatment

- Initial stabilization
  - Administer IV fluids to restore intravascular volume.
  - Give nothing by mouth.
  - Administer antibiotics if the patient will be going to the operating room.
  - Place an NG tube to suction.
- Laboratory tests include complete blood count, electrolytes, blood urea nitrogen, glucose, and creatinine.
- Attempt hydrostatic reduction using water-soluble diatrizoate sodium or air enema (contraindicated in the presence of peritonitis or pneumoperitoneum).
- Suspend the enema bag no higher than 1 m above the anus. Hold for 3 minutes and limit to 3 attempts.
- Insufflation of air (maximum pressure of 80–120 mmHg) via a rectal tube is an alternate method to attempt reduction.
- To be considered a successful reduction, contrast must pass into the terminal ileum.
- If reduction is unsuccessful, operative exploration and reduction are indicated.
- Nonoperative treatment is effective more than 80% of the time.

- Recurrence rate is 5% to 7%.
  - Diagnose using air or contrast enema.
  - After the second recurrence, operative intervention is indicated because of the high likelihood of a pathologic lead point.
  - If contrast or air reduction is unsuccessful, or if physical examination reveals a tender or rigid abdomen:
    - Perform laparotomy using a transverse, right lower incision.
    - Attempt manual reduction by gently milking the intussusceptum out of the intussuscipiens (never pull it out).
    - Perform an appendectomy and resection of frankly gangrenous bowel or lead point (eg, Meckel's diverticulitis) if present, and an ileocecostomy with primary ileocolic anastomosis.
  - Postoperative intussusception is evident by a small bowel obstruction in the early postoperative period (around postoperative day 5). It most commonly occurs as an

ileoileal intussusception and no attempt should be made at radiographic reduction. Treat with manual, operative reduction.

Meconium Disease

- Meconium ileus
  - Meconium ileus is a generalized mucoviscidosis of exocrine secretions, resulting in inspissated meconium causing intraluminal intestinal obstruction in a newborn.
  - It affects all exocrine glands and is usually associated with cystic fibrosis.
  - Bronchi and alveoli are obstructed by thick mucoid secretions.
  - Pancreatic ducts are obstructed, leading to recurrent pancreatitis.
  - Intestinal involvement is characterized by obstruction resulting from thick, viscous mucus as water migrates out of the intestinal lumen.
  - Other organs affected include sweat and salivary glands, nasal mucus membranes, and reproductive organs (males are sterile).
  - Differential diagnosis includes Hirschsprung's disease (especially total aganglionosis), hypothyroidism, small left colon syndrome, colonic or ileal atresia, and meconium plug syndrome.
  - Radiographic findings (on abdominal radiograph) include
    - Multiple distended loops of intestine mimicking small bowel obstruction, but air–fluid levels are rarely present because of the viscosity of the intraluminal meconium and because the bowel is completely filled with fluid or meconium.
    - Course, granular, soap-bubble ("ground glass") appearance due to the presence of air within thick meconium (Neuhauser sign).
    - Prenatal perforation with meconium peritonitis and complicated meconium ileus (due to liberated lipases and bile salts) resulting in calcium deposition (saponification). Uncomplicated meconium ileus will show no clinical or radiographic evidence of perforation or peritonitis.

- Prominent air–fluid levels suggesting intestinal atresia or volvulus, which is usually associated with a gasless abdomen.
- Ascites and pneumoperitoneum indicative of postnatal colonic perforation.

- Nonoperative treatment
  - Ensure the patient is well hydrated.
  - Insert an NG tube.
  - Administer broad-spectrum antibiotics (ampicillin and gentamicin).
  - Perform fluoroscopically visualized enema with a hyperosmolar agent (meglumine diatrizoate or N-acetylcysteine).
- Operative treatment
  - Operative treatment is indicated for complicated patients (ie, those with perforation or peritoneal signs, volvulus, gangrene, or atresia) or after a failed attempt at nonoperative treatment.
  - Technique
    - Perform enterotomy at ileum or appendectomy (with irrigation and drainage) through the appendiceal stump (to avoid an anastomosis or ileostomy). Send appendix to pathologist to check for presence of ganglion cells to rule out Hirschsprung's disease.
    - Run the entire length of the bowel to rule out areas of necrosis or atresia. If any are discovered, they should be resected.
    - Pass a red rubber catheter proximally and distally
    - Irrigate with saline or N-acetylcysteine (mucolytic).
    - Perform a primary anastomosis, ileostomy and mucus fistula or Bishop-Koop end-to-side (proximal dilated bowel to side) anastomosis, Santulli anastomosis (proximal ileostomy with end-to-side anastomosis), or tube ileostomy.
    - Administer antibiotics for 3 days.
    - Continue NG suction and later consider 10% N-acetylcysteine by gastric tube, if needed.
    - Patient may require rectal irrigations.
    - Initiate oral feedings and pancreatic enzymes 5 to 10 days after operation.

- Meconium plug syndrome
  - Meconium plug syndrome develops when a newborn fails to excrete fetal meconium from the colon.
  - Symptoms include abdominal distention and colonic obstruction resulting from a plug of inspissated meconium, which is usually whitish gray distally, green proximally.
  - Physical findings include obstructing meconium and colonic hypomotility.
  - Differential diagnosis includes Hirschsprung's disease, hypokalemia, hypocalcemia, and increased glycogen.
  - Meconium plug syndrome is associated with hypoglycemia in infants of diabetic mothers. It is not usually associated with cystic fibrosis.
  - Abdominal radiograph will reveal multiple loops of dilated bowel; however, it is difficult to distinguish between large and small bowel in a neonate.
  - Treat with diatrizoate sodium enema. Operation is rarely necessary (rule out Hirschsprung's disease by rectal biopsy).

Large Intestine

Acute Appendicitis

- Acute appendicitis is the most common acute surgical condition of the abdomen; it parallels the amount of lymphoid tissue in the appendix (peak incidence is during the mid-teenage years).
- Fecaliths, which obstruct the lumen, are the most common cause of luminal obstruction and the most common factor in the etiology of acute appendicitis. Other causes include lymphoid hyperplasia, seeds, and worms (eg, pinworms, Ascaris).
- Pathophysiology
  - Acute appendicitis begins with an obstruction of the lumen. Normal mucosal secretion continues, followed by bacterial overgrowth, then appendiceal distention.
  - Nerve endings of visceral afferent sympathetic pain fibers are stimulated through the celiac ganglion to the tenth thoracic segment causing vague, dull, diffuse pain in the

midabdomen or lower epigastrium; this pain is referred to the umbilical area (tenth dermatome).
  - Parietal peritoneum becomes irritated by the inflamed appendix, causing pain to be localized to the right lower quadrant.
  - Stimulation of peristalsis leads to cramping pain.
  - Appendiceal distention increases secondary to bacterial proliferation, which produces reflex nausea and vomiting.
  - Venous pressure is exceeded while arterial inflow continues, resulting in engorgement and vascular congestion.
  - Bacteria from the lumen translocate into the bloodstream.
  - Reflex nausea and vomiting result, as does severe visceral pain, from the increased distention.
  - The appendiceal wall becomes infarcted, resulting in gangrene, perforation, and peritonitis.
- Symptoms
  - **Localized pain in the right lower quadrant** is the most important diagnostic finding on physical examination.
  - Pain is initially centered in the lower epigastrium or periumbilical area (serosa of the appendix becomes inflamed and pain localizes to the right lower quadrant after 4–6 h as a result of parietal peritoneal inflammation).
- Anatomical locations
  - A long or retrocecal appendix with an inflamed appendiceal tip results in pelvic pain.
  - If the inflamed appendix lies near the ureter or bladder, appendicitis may occur at a retrocecal location (two-thirds of all cases of appendicitis occur here) and present as flank or back pain (most commonly), nausea, vomiting, and increased white blood cell count; microscopic hematuria or pyuria may occur.
  - Appendicitis at a pelvic location presents as suprapubic pain from an inflamed tip lying against the bladder, which may cause urinary frequency and dysuria.
    - If there is tenderness on a rectal examination, the inflamed tip is most likely lying adjacent to the rectum.
    - An abscess may present with severe urinary symptoms and diarrhea.

- Appendicitis at a retroileal location results in testicular pain from irritation of the spermatic artery and ureter; anorexia almost always accompanies appendicitis (if a child is truly hungry, appendicitis is unlikely).
- Vomiting is frequent.
- Symptoms usually progress from anorexia, to abdominal pain, to nausea with vomiting; if vomiting precedes the onset of abdominal pain, the diagnosis should be questioned (in favor of gastroenteritis).
- High-grade fever (greater than 100°F, 38°C) is rare except in cases of perforation with peritonitis.
- The most important physical finding is point tenderness over McBurney's point (at the junction of the lateral one-third and medial two-thirds of a line from the anterior superior iliac spine to the umbilicus), usually accompanied by guarding and muscle spasm.
- Individual may also show
  - Psoas sign (pain on extension of the right thigh, which, when the patient is in the lateral decubitus position, stretches the irritated iliopsoas muscle).
  - Obturator sign (passive internal and external rotation of the flexed right thigh stretches the obturator internus muscle, producing pain).
  - Rovsing's sign (pain in the right lower quadrant upon palpation of the left lower quadrant).
- Cutaneous hyperesthesia will be seen in segments T10, T11, and T12.
- Preoperative diagnosis based on medical history and physical examination should be correct in 85% to 90% of cases.
- Symptoms are secondary to bacterial toxins and absorption of dead tissue toxins and include fever, tachycardia, hypotension, and leukocytosis.

- Laboratory findings
  - White blood cell count will be about 10,000 to 18,000, with left shift. Counts greater than 18,000 are indicative of a perforation.
  - Infants and young children may be unable to mount an increased white blood cell count, delaying diagnosis and leading to an increased incidence of rupture.

- Obtain a urinalysis to rule out a urinary tract infection and pregnancy.
- Ultrasound will show the appendiceal diameter to be greater than 7 to 8 mm, edema, periappendiceal fluid, and fat stranding. Rule out gynecological problems such as ovarian cysts and tubal pregnancy.
  - A gas-filled appendix usually indicates appendicitis with proximal obstruction.
  - A distended loop of small bowel may be present in the right lower quadrant ("sentinel loop").
  - Multiple loops of distended small intestine may significantly hamper visualization of the appendix on ultrasound.
- Take a chest radiograph to rule out right lower lobe pneumonia.
- A CT scan (with oral and IV contrast) will often reveal inflammation, fat stranding, and fluid; however, CT scan should be reserved for patients with a questionable diagnosis of appendicitis to minimize radiation exposure. Patients with a clear clinical history and examination for appendicitis do not require a CT scan.

- Complications of appendicitis occur in approximately 5% of cases but increase with perforated appendicitis. They include
  - Superficial wound or port-site infection. Treat by reopening the skin and subcutaneous tissue, and begin saline wet-to-dry dressing. Administer broad-spectrum antibiotics and consider methicillin-resistant *Staphylococcus aureus* coverage, if needed.
  - Pelvic abscess, the most common complication of ruptured appendicitis. Treat with antibiotics and image-directed catheter drainage, depending on size and location.
  - Ileus. Place an NG tube and administer IV fluids.
  - Small bowel obstruction. Initially, place an NG tube. If the obstruction fails to resolve, operate again, lysing adhesions.
  - Appendiceal stump blowout. Drain or perform a tube cecostomy.
- Prognosis
  - The principal factor determining mortality is rupture.
    - Unruptured: 0.1% mortality.

    - Ruptured: 3% mortality.
    - Cause of death is usually uncontrolled gram-negative sepsis.
    - Appendiceal rupture
        - Deaths from appendicitis are almost always secondary to complications of perforation, resulting in gram-negative sepsis (*E coli* and *Bacteroides* are the most common organisms). Incidence of appendiceal rupture is significantly higher in pediatric and geriatric age groups due to delayed diagnosis.
        - Young children may not be able to form a phlegmon to wall-off a perforation or abscess because of a paucity of omentum.
- Symptoms
    - Temporary pain relief after perforation is rare; localized pain progresses to encompass the entire right lower quadrant.
    - A tender, boggy mass in the peritoneal area indicates the presence of a phlegmon or abscess.
    - Symptoms usually last greater than 36 hours and include temperature elevation between 102°F and 104°F (39°C to 40°C), increased white blood cell count (20,000 to 35,000 with extreme left shift), and hemoconcentration.
    - Pylethrombophlebitis (septic thrombophlebitis of the portal vein) is a complication of gangrenous appendicitis heralded by chills, spiking fever, right lower quadrant pain, and jaundice. Septic clots may embolize to the liver, producing multiple pyogenic abscesses.
    - The most common sites of seeding from an appendiceal perforation are the pouch of Douglas (pelvic cul-de-sac) and the right subhepatic space (via the right gutter).
- Preoperative diagnosis should be made correctly in approximately 85% to 90% of cases and depends on three major factors:
    - anatomical location of the inflamed appendix,
    - stage of the process (simple or ruptured), and
    - age and sex of the patient (harder to diagnose in young females).
- Appendicitis during pregnancy

- This is the most common extrauterine surgical emergency (though incidence of appendicitis is not increased by pregnancy).
- White blood cell count normally increases in pregnancy, but a left shift is abnormal.
- The appendix moves superiorly and laterally as pregnancy progresses.
- Laparoscopy may be helpful if diagnosis is uncertain.
- The fetal mortality rate from maternal appendicitis is 8.5%; the rate of fetal mortality from maternal perforation and peritonitis increases to 35%.
- Treat by NG tube decompression and providing IV fluids and preoperative antibiotics appropriate to cover *Bacteroides fragilis* (gram-negative rod; eg, cefotetan or clindamycin).
- Nonoperative management may be appropriate to treat a periappendiceal abscess.
- Drain the abscess percutaneously or operatively.
- If symptoms regress, manage conservatively.
- If needed, perform an interval appendectomy at 6 to 8 weeks.
- If appendicitis is not found,
  - rule out adnexal disease (if tuboovarian abscess is found, incise and drain only, do not resect tube or ovary),
  - examine the mesentery for adenopathy (mesenteric lymphadenitis), and
  - examine the small bowel for a distance of about 3 ft to rule out Crohn's disease, ulcerative colitis, terminal ileitis, and Meckel's diverticulitis.

- Gynecological disorders are important in the differential diagnosis of appendicitis.
  - Gynecological disorders compose the highest rate of missed diagnoses in young adult females.
  - Differential diagnosis includes pelvic inflammatory disease (the most common erroneous diagnosis), ruptured Graafian follicle (mittelschmerz), and ruptured ectopic pregnancy.
- Diseases in males that may cause lower abdominal pain include torsion of the testis and acute epididymitis (see Chapter 24, Genitourinary Tract).

- Urinary tract infections may cause lower abdominal pain and are part of the differential diagnosis of appendicitis (see Chapter 24, Genitourinary Tract).
  - Symptoms of urinary tract infection include urinary frequency and dysuria.
  - Suprapubic or costovertebral angle tenderness is evident on physical examination.
  - The patient's temperature will be greater than 101°F (about 38°C).
  - Urinalysis shows pyuria, hematuria, elevated leukocyte esterase, and nitrites.
- Ureteral stones (urolithiasis) may also cause flank and lower abdominal pain (see Chapter 24, Genitourinary Tract).
  - Ureteral stones manifest as severe colicky abdominal or flank pain that radiates to the pelvis.
  - Laboratory findings show hematuria but neither fever nor increased white blood cell count.
  - Renal ultrasound and complete urologic evaluation are required for pediatric patients.
  - Treatment consists of pain control, IV hydration, metabolic studies, and stone analysis, where feasible.

Acute Gastroenteritis

- Etiologies
  - The viral form of acute gastroenteritis is manifest by profuse watery diarrhea, nausea, and vomiting. Hyperperistaltic abdominal cramps precede watery stools, and vomiting precedes the onset of abdominal pain. Complete blood count is usually normal or may show a right shift (increased lymphocytes).
  - Bacterial gastroenteritis caused by Salmonella and Shigella often results from the ingestion of contaminated food. Symptoms include bloody diarrhea, skin rash, bradycardia, leukopenia, chills, and fever.
    - Typhoid fever is usually due to *Salmonella typhosa*, which is cultured from stool or blood. Symptoms include maculopapular rash, bradycardia, leukopenia, and ileal perforation (in 1% of cases).

    - Treat with chloramphenicol.
  - Bacterial caused by *Yersinia enterocolitica* or Campylobacter results from ingesting food contaminated by feces or urine.
    - Symptoms include cervical and mesenteric lymphadenitis, ileus, and colitis.
    - Treat with ampicillin or gentamicin.

Primary Peritonitis

- Primary peritonitis is rare in children. When it does occur, it usually affects children between the ages of 2 and 6 years old. It is more common in females than in males.
- Symptoms include abdominal pain and fever, with or without nausea or vomiting.
- Physical findings include fever, tachycardia, and diffuse peritonitis.
- Diagnose with peritoneal aspiration. If only a single species of streptococci is seen, the patient has primary peritonitis and needs medical treatment. If mixed flora is seen, the patient has secondary peritonitis and the etiology must be investigated.
- If operation is performed, thoroughly evaluate the patient for appendicitis or bowel perforation. Most operations are negative. Cultures of ascetic fluid should be performed with abdominal irrigation using normal saline.

Henoch-Schönlein Purpura

- Henoch-Schönlein purpura usually occurs 2 to 3 weeks following an upper respiratory infection.
- Most children with Henoch-Schönlein purpura are 2 to 6 years old.
- Symptoms include crampy abdominal pain, palpable purpuric rash, rectal bleeding, and small bowel intussusception.
- Laboratory findings include thrombocytopenia, elevated blood urea nitrogen, and proteinuria.
- Treat with bed rest, fluids, and systemic corticosteroids. Surgery is only indicated for severe intussusception that cannot be reduced nonoperatively.

Hemolytic Uremic Syndrome

- Hemolytic uremic syndrome is caused by a specific strain of *E coli* (O157/H7) found in contaminated meat or fecal-contaminated pools and lakes.
- Symptoms include bloody diarrhea, abdominal pain, vomiting, low-grade fever, hematuria, acute renal failure, and, rarely, seizures.
- Laboratory findings include anemia (secondary to hemolysis), leukocytosis, thrombocytopenia, hematuria, and uremia.

Constipation

- Symptoms of constipation include cramping abdominal pain with decreased bowel movements, excessive straining during defecation, nausea, vomiting, and incomplete evacuation of stools.
- In young children, a hard, stool-filled colon is evident on palpation.
- Laboratory tests usually show normal values.
- Abdominal radiographs typically show a large stool burden.
- Treat with hydration, dietary modifications, stool softeners, laxatives, or enemas.

Pneumonia

- Physical findings of pneumonia include rales in the right lower lobe and an absence of point abdominal tenderness.
- Diagnosis is made by chest radiograph, which demonstrates focal infiltrates in the right lower lobe.

Typhlitis

- Typhlitis is a bacterial invasion of the intestinal wall (usually cecum).
- It is usually seen in immunocompromised patients (eg, those with cancer, HIV, on immunosuppressive therapy, or transplant patients).
- Patients at highest risk are those with absolute neutrophil counts less than 1,000 cells per microliter.
- Symptoms include right lower quadrant abdominal pain and neutropenia (mimics appendicitis).

- CT scan reveals inflammation of the right colon and terminal ileum.
- Treatment is typically nonoperative because of high mortality. Broad-spectrum antibiotics and serial examinations are recommended and operative intervention is only indicated for perforation.

Hirschsprung's Disease (Congenital Megacolon)

- Normally, neural crest cells form neuroblasts, which migrate in a craniocaudal direction to the distal rectum in the twelfth week of gestation, becoming enteric ganglion cells (Auerbach [myenteric] plexus, and Meissner's [submucosal] plexus).
- Pathology
  - Absence of submucosal ganglion cells (Meissner's plexus) and intramuscular plexus (Auerbach plexus).
  - Enlarged, hypertrophic, nonmyelinated nerve fibers result in enlarged nerve trunks in the submucosa, muscularis mucosa, and Auerbach intramuscular plexus.
  - Increased acetylcholinesterase in postsynaptic muscularis.
  - Calretinin staining for neural tissue can assist in the diagnosis, as well.
  - The most common site of aganglionosis is the rectosigmoid due to arrested migration of neuroblasts (80%).
- Symptoms include
  - Failure to pass meconium within 48 hours after birth. Premature infants have a higher failure rate in passing meconium, but Hirschsprung's disease is more common in term infants.
  - GI tract obstruction (distention, bilious vomiting).
  - Enterocolitis (the major cause of morbidity and mortality).
  - Fecal soiling. Although this is rare, there is increased incidence in patients with trisomy 13.
- Differential diagnosis includes
  - (In neonates) sepsis, necrotizing enterocolitis-associated stricture, meconium plug or ileus, and intestinal atresias.
  - Habit constipation associated with a full rectal ampulla and fecal soiling. In Hirschsprung's disease, the rectal ampulla is usually empty.

  - Functional constipation (infrequent, large, firm stools accompanied by pain and bleeding from anal fissures). A history of normal stool frequency during infancy is associated with functional constipation, not with Hirschsprung's disease.
  - Hypothyroidism.
- Diagnosis (**NOTE**: Due to the special stains and expertise needed to diagnose Hirschsprung's disease, no attempt should be made to provide definitive treatment. End ileostomy is recommended if Hirschsprung's is suspected and the patient cannot be transferred to a facility offering advanced pediatric surgical care.)
  - Perform rectal biopsy (suction or full-thickness) to rule out retained Hirschsprung's disease.
  - Perform a contrast enema.
    - A conical transition zone from the distal, nondilated, aganglionic colon or rectum to the proximal (ganglionic) dilated colon is seen on contrast enema.
    - A transition zone may be absent in neonates.
    - A contrast enema excludes other causes of colonic obstruction, including small left colon syndrome, meconium plug syndrome, and atresia.
  - Nonsurgical treatment (recommend in limited-resource environment)
    - NG tube decompression in the upper GI tract.
    - Administer IV fluids and antibiotics (ampicillin, gentamicin, and metronidazole).
    - Perform rectal irrigations with 20 cc/kg warm Ringer's lactate three times daily using a soft, rubber catheter.
    - If the above measures are unhelpful and the patient cannot be urgently transferred to the care of a pediatric surgeon, consider performing a colostomy.
  - Surgical treatment
    - Perform a leveling colostomy of normally innervated (biopsy-proven) bowel.
    - If no clear-cut transition zone can be determined, the patient may have total colonic aganglionosis. If a biopsy diagnosis is unobtainable, perform an ileostomy.
    - Refer the patient to a facility with pediatric surgery capability, if possible.

- Hirschsprung's-associated enterocolitis is a potentially lethal complication.
  - Symptoms include abdominal distention, diarrhea, vomiting, fever, lethargy, and, if severe, sepsis and perforation.
  - This complication usually occurs in children less than 3 years old and is the most common cause of death in affected children.
  - It may occur before or after colostomy or pull-through.
  - Laboratory tests show high levels of *C difficile* toxin and elevated white blood cell count.

Rectum and Anus

Rectal Prolapse (Procidentia)

- True prolapse is present when there are circular folds of full-thickness bowel. Pseudo prolapse involves radial folds of mucosa only.
- Treatment
  - Temporarily, tape buttocks together to achieve manual reduction.
  - Rule out cystic fibrosis and parasites.
  - Discourage the patient from prolonged sitting or straining during a bowel movement.
  - Prescribe stool softeners.
  - Administer submucosal injection hypertonic glucose (50%) or hypertonic saline (20%).
  - Administer 5 cc per treatment.
  - Use a #18 spinal needle for four-quadrant sclerosis. Inject 2 cc posteriorly and 1 cc in the other three quadrants (almost all cases will resolve spontaneously without an operative procedure).

Anal Fissure

- Anal fissures are the most common cause of rectal bleeding in newborns.
- Symptoms include blood streaks on the outside of stool and constipation.

- Physical examination will show superficial tear of the anal mucosa, usually in the posterior midline. A sentinel skin tag indicates a chronic fissure. Fifty percent of anal fissures are associated with fistula-in-ano (see below).
- Anal fissures are caused by stretching and tearing during evacuation of large, hard stools.
- Nonoperative treatment consists of stool softeners, dilatation (may require manual stretch under sedation), and sitz baths.
- Operative treatment includes partial lateral internal sphincterotomy and botulinum toxin injection.

Perianal and Perirectal Abscess

- In infants, perianal and perirectal abscesses can develop from an infected diaper rash. In children, rule out Crohn's disease, leukemia, and immunodeficiency syndromes.
- Symptoms include fever and pain.
- Treat with incision, drainage, and sitz baths.
- Abscesses may be associated with a fistula-in-ano (see below).

Fistula-in-Ano

- Fistula-in-ano results from a perianal abscess extending from a crypt to the perianal skin (suspect when an abscess recurs).
- Treat with fistulotomy (over a probe), tract curettage, or, if fistula is complex or high, place a seton tie.
- Older patients with multiple fistulas should be evaluated for Crohn's disease.

Imperforate Anus

- Imperforate anus is diagnosed clinically by an absence of an anal opening or abnormal location of the anal orifice (rectoperineal or rectovestibular fistula).
- Evaluate for associated VACTERL defects (especially cardiac defects).
- Treat initially with NG tube decompression and IV hydration, and transfer patient to a center with pediatric surgical capabilities.
- If the patient cannot be transferred, perform a descending colostomy and mucus fistula.

Preoperative Mechanical Bowel Preparation

- Give polyethylene glycol electrolyte solution (25–35 cc/kg/h for 4–6 h via an NG tube; safe in infants and children). Recent literature shows an increase in infection in children treated in this manner; use selectively.
- Add an oral erythromycin base and neomycin.

Chapter 22

Hepatobiliary Tract

Liver

Trauma

- Diagnosis
  - Use computed tomography (CT) scan with intravenous (IV) and oral contrast to rule out associated injury to the upper gastrointestinal tract. It is imperative that the patient be hemodynamically stabilized prior to transport from the resuscitation area (eg, triage area, emergency department trauma bay, etc) to radiology.
  - Focused assessment with sonography for trauma (FAST) examination may also aid diagnosis. In pediatric patients, this is not a proven, reliable test and should only be considered to have excluded injury in patients who have a very low likelihood of injury.
  - Diagnostic peritoneal lavage.
- Treatment
  - Nonoperative management for hemodynamically stable patients consists of serial examinations, including serial hematocrits, to detect ongoing blood loss. Typed and cross-matched blood should be readily available if needed. The current American Pediatric Surgical Association guidelines are as follows. (Abbreviated protocols are being studied. Shorter hospitalization length and discharge activity restriction may be appropriate.)
    - Put patient on bed rest in the hospital for injury grade + 1 day.
    - Intensive care unit observation is only required for grade IV injuries.
    - Discharge activity restriction period = (injury grade + 2 weeks).

- Laparotomy may be indicated for persistent hemodynamic instability and ongoing blood loss (greater than 50% of blood volume or 40 cc/kg of packed red blood cells transfused).
  - Consider activating massive transfusion protocol.
  - The primary goal is to stop the bleeding and "get out" before the lethal triad of coagulopathy, acidosis, and hypothermia develops. This is the basis for "damage control" surgery.
  - Pack the abdomen with gauze sponges upon initial entry.
  - In a patient with trauma involving multiple organ systems, give early consideration to damage control (it is essential to make this decision before irreversible shock develops).
    - Leave the abdomen packed with gauze sponges.
    - Apply a temporary abdominal closure (using a vacuum device).
    - Resuscitate in the intensive care unit (correct hypothermia, acidosis, and hypotension).
    - Re-explore the abdomen in 24 to 48 hours.
  - Debride devitalized tissue using the "finger fracture" technique.
  - Perform direct suture ligation of bleeding vessels.
  - Control bleeding.
    - Clamp the hepatoduodenal ligament, which contains the hepatic artery, portal vein, and common bile duct (Pringle maneuver).
    - Obtain proximal and distal control of the vena cava.
  - Parenchymal bleeding may be controlled with chromic sutures swedged on blunt liver needles and placed over omental "pledgets."

Hemobilia

- Hemobilia is a sequelae of hepatobiliary tract trauma.
- Symptoms include a triad of right upper quadrant pain, bleeding from the upper gastrointestinal tract (hematemesis or melena), and hyperbilirubinemia.
- Diagnose with angiography or CT scan.
- Treatment with selective embolization is preferred over surgical exploration.

Infections

- Pyogenic abscesses
  - Etiology
    - intraabdominal source of bacteria (eg, from intestinal perforation);
    - penetrating or blunt liver trauma;
    - cholangitis;
    - chronic malnutrition;
    - granulocyte dysfunction;
    - sickle cell disease, thalassemia; or
    - congenital or acquired immunosuppression.
  - Overwhelming postsplenectomy infection
    - Diagnosis is often delayed because of a low index of suspicion.
    - Signs and symptoms are rare and develop slowly. They include
      - fever (often prolonged),
      - abdominal pain,
      - hepatomegaly, and
      - nausea, vomiting, anorexia, and weight loss.
    - Laboratory studies are generally not helpful in diagnosis.
      - About 50% of patients will show mild leukocytosis.
      - Inflammatory markers (eg, C-reactive protein) will be elevated.
    - Bacteriology
      - The most important pathogen is *Streptococcus pneumoniae*, but *Haemophilus influenza* and *Neisseria meningitidis* are also significant.
      - Anaerobes may also be responsible for infection.
    - Peripheral blood cultures are generally not helpful; they are often negative or do not reflect bacteriology of hepatic abscesses.
    - Diagnose using ultrasound and CT scan.
    - Treatment
      - Administer broad-spectrum antibiotics for a minimum 4 weeks total: 2 to 4 weeks parenteral antibiotics, then oral antibiotics for the remainder of the course.
      - Perform image-guided (ultrasound, fluoroscopy) drainage.

        - Surgically drain if the infection does not respond to the above measures.
        - Surgically drain multiloculated abscesses.
- Amebic abscess
  - Etiology
    - Poor sanitation and crowded conditions can lead to fecal-oral transmission.
    - *Emtamoeba histolytica* is the most common organism responsible.
    - Colitis is a major causative factor in pediatric diarrhea deaths in developing countries.
    - Signs and symptoms include
      - fevers, chills;
      - right upper quadrant pain that may radiate to the shoulder or have a pleuritic quality;
      - nausea, weight loss, recent history of diarrhea; and
      - abdominal distention, hepatomegaly.
    - Diagnose with ultrasound, CT scan, and serologic testing.
    - Treatment
      - Give oral metronidazole (30–50 mg/kg/day divided 3 times per day for 7–10 days).
      - Drainage and surgery are not indicated unless the abscess is at risk for rupture or treatment failure (ie, if the patient has fever and pain after completing 3–5 days of medical therapy).
    - Complications
      - Intraperitoneal rupture carries up to a 75% mortality rate.
      - Rupture can also occur into the chest, pericardium, and surrounding intraabdominal organs.
      - Hematogenous spread may infect the central nervous system and skin.
- Hydatid cysts
  - Etiology: *Echinococcus granulosis,* the larval stage of the dog tapeworm. Ingested ova burrow through the intestinal mucosa and become trapped in the liver (60%), lung (20%), and other organs (20%).
  - Hydatid cysts are usually solitary.

        - A pericyst develops around the hydatid cyst.
        - Calcifications may be present in the cyst rim.
        - Hydatid cysts may develop daughter cysts.
    - Rupture may initiate an anaphylactic reaction.
    - The cyst may become secondarily infected.
    - Diagnose using ultrasound, CT scan, and serologic testing.
    - Treatment
        - Surgery is definitive.
            - Pack off the liver to protect the remainder of the abdomen; avoid spillage-induced anaphylaxis.
            - Aspirate the cyst.
            - Open the cyst to excise the remaining contents and surrounding pericyst.
        - Perioperative use of anthelmintic drugs decreases incidence of recurrence.
- Masses
    - Benign masses include hemangioma, arteriovenous malformation, mesenchymal hamartoma, biliary cystadenoma, hepatocellular adenoma, focal nodular hyperplasia, teratoma, inflammatory pseudotumor, and nonparasitic cysts.
    - Malignant masses include hepatoblastoma, hepatocellular carcinoma, sarcoma, and metastatic disease.
    - The majority of pediatric liver masses require resection and possibly chemotherapy. These lesions should therefore be referred to tertiary treatment centers, as successful treatment in the hostile environment is unlikely.

Biliary Tract

Trauma

- Nonoperative management of blunt biliary tract trauma carries a 4% risk of persistent bile leak.
    - Diagnose using radionuclide scanning, if available.
    - Treat with endoscopic retrograde cholangiopancreatography (ERCP) and stent placement, if available.
    - Perform cholecystectomy for traumatic gallbladder injuries.
    - Incomplete common bile duct injuries may be repaired over a T-tube.

- For extensive extrahepatic biliary tract injuries, use tube choledochostomy for damage control and hepaticojejunostomy or choledochoduodenostomy for definitive repair.

Gallbladder Disease

- In developing countries, hemolytic disease, such as hereditary spherocytosis, sickle cell disease, thalassemia major, and hemolytic anemia, is the most likely etiology of cholelithiasis. The nature of the underlying hemolytic disease will vary with geography.
- Treatment
  - Perform cholecystectomy for acute calculous cholecystitis and symptomatic cholelithiasis, and consider it for asymptomatic patients with an underlying hemolytic condition, especially if the patient will be undergoing splenectomy.
  - Placement of a cholecystotomy tube instead of a cholecystectomy may be appropriate depending on the condition of the patient and available resources.
  - Careful perioperative management of hemolytic disorders may avoid associated medical crisis.
    - Avoid elective surgery in patients with active infection.
    - Use simple transfusion to achieve a hemoglobin level of 10 g/dL.
  - Higher hemoglobin levels can increase blood viscosity.
  - Higher-risk patients should be evaluated by a hematologist.
    - Keep the patient adequately hydrated and oxygenated.
    - Avoid intraoperative hypothermia and acidosis due to hypovolemia.
  - Ensure adequate postoperative hydration, provide supplemental oxygenation as required, and monitor pulse oximetry to maintain a level of at least 94% saturation.

Acalculous Cholecystitis/Hydrops

- Acalculous cholecystitis and hydrops are associated with sepsis, multisystem trauma, burns, total parenteral nutrition, and Kawasaki disease.
- Symptoms include fever, right upper quadrant tenderness, guarding, and leukocytosis.

- Sonography will show gallbladder distension and echogenic debris ("sludge"). Radionuclide scanning is also useful for diagnosis, if it is available.
- Treatment
  - Initially, treat conservatively with antibiotics and reinstitute enteral feedings when appropriate.
  - Perform cholecystectomy, or cholecystostomy in patients unable to tolerate cholecystectomy.

Choledocholithiasis

- Symptoms include increased direct (conjugated) bilirubin, abdominal pain, fever, and nausea. If amylase is also increased, consider choledocholithiasis with pancreatitis.
- Treat with
  - Endoscopic retrograde cholangiopancreatography (ERCP) preoperatively, if available.
  - Intraoperative cholangiogram.
  - Open or laparoscopic exploration.
  - Cholecystotomy (in certain circumstances).

Choledochal Cyst

- Diagnosis, treatment, and long-term management of this condition may be challenging in the hostile environment. Strongly consider referring the patient to a tertiary care facility.
- A choledochal cyst involves a cystic dilatation of the biliary tree.
- Etiology is not fully understood.
- Symptoms include the classic triad: right upper quadrant pain, jaundice, and a palpable mass.
- Classification
  - Type I: dilation of the common bile duct.
  - Type II: diverticulum coming off of the common bile duct.
  - Type III: choledochocele.
  - Type IV: intra- and extrahepatic dilation of the biliary tree.
  - Type V: single or multiple intrahepatic cysts (Caroli disease).
- Treatment
  - Provide treatment to alleviate obstructive symptoms and decrease long-term risk of malignant changes.

- Type I: cystectomy with hepaticojejunostomy or hepaticoduodenostomy.
- Type II: simple excision of the diverticulum.
- Type III: marsupialization of the cyst via ERCP or transduodenal incision.
- Type IV: excise the dilated extrahepatic biliary tree and reconstruct by performing a hepaticojejunostomy or hepaticoduodenostomy.
- Type V: segmental resection if disease is confined to one portion of the liver or for possible liver transplantation.

(*The remaining biliary conditions are unlikely to be encountered in the hostile environment and should be referred to tertiary care centers if encountered*.)

Biliary Atresia

- Biliary atresia is a rare obstructive disease of the biliary tract that causes persistent jaundice beginning in the neonatal period; no clear etiology has been identified.
- Physical examination will show
  - jaundice (should be considered pathologic when the direct fraction of bilirubin remains elevated beyond 7–10 days of life);
  - light (acholic), gray-colored stools due to the absence of bile pigment;
  - dark urine due to increased bilirubin excretion; and
  - hepatomegaly.
- Laboratory tests will show direct (conjugated) hyperbilirubinemia (more than 3 mg/dL for patients 2 weeks of age and older). Biliary atresia is the most common cause of conjugated hyperbilirubinemia in a 1-month-old infant.
- Diagnosis is made by ultrasonography, magnetic resonance and CT cholangiography, radionuclide studies, intraoperative cholangiogram, and liver biopsy.
- Treatment in a hostile environment is not appropriate; patients should be expeditiously referred to a pediatric center for evaluation and treatment, if available. Hepatoportoenterostomy (Kasai procedure) is the initial surgical treatment; up to two-thirds of patients will ultimately require liver transplantation.

Biliary Hypoplasia

- Biliary hypoplasia is not a specific disease entity, but a manifestation of a variety of hepatobiliary disorders including
  - neonatal hepatitis,
  - alpha-1 antitrypsin deficiency,
  - early intrahepatic biliary atresia, and
  - Alagille syndrome (arteriohepatic dysplasia).
- Diminutive ducts will be seen on cholangiography.
- Manage nonoperatively with choleretics (eg, ursodeoxycholic acid, phenobarbital).

Inspissated Bile Syndrome

- Inspissated bile syndrome may result from massive hemolysis due to Rhesus factor and ABO incompatibility (resulting in obstruction from sludge in the biliary tract), total parenteral nutrition (TPN)-associated cholestasis, or cystic fibrosis.
- Treat with choleretic agents and cholangiogram via the gallbladder with irrigation of the biliary tree.

Biliary Ascites

- Biliary ascites is seen in infants after perforation of extrahepatic bile duct.
- Diagnosis is made by radionuclide scanning, if available.
- Treat via cholecystostomy with drainage of the porta hepatis. Suture repair of the perforation is not recommended. Postoperative cholangiogram can be performed via a cholecystostomy tube to confirm healing prior to tube removal.

Chapter 23

Pancreas and Spleen

Injury to the pancreas and spleen may result from blunt or penetrating forces. Treating major pancreatic trauma, and its frequent complications, is often problematic in even the best-equipped medical facilities. A "damage control" approach should be practiced in echelons of care below those of a full-service hospital. While operations for "splenic salvage" are preferred where feasible, this is a dangerous approach in an environment where blood product transfusion may be limited and when patient evacuation may occur in the early postoperative period. Under these circumstances, splenectomy constitutes the most prudent procedure.

Pancreas

Congenital Variations

- Ectopic pancreatic tissue
  - Pancreatic tissue may be functional and the patient may demonstrate adverse symptoms.
  - If a Meckel's diverticulum contains pancreatic tissue, diverticulitis or painless, bright red bleeding from adjacent intestinal mucosa may be manifest.
    - Exocrine function remains normal.
    - Treatment: diverticulectomy or sleeve resection of the ulcerated bowel if the patient is symptomatic.
- Annular pancreas
  - Anatomy: pancreatic tissue circumferentially surrounds the second portion of the duodenum at the region of the sphincter of Oddi.
  - Parenchymal and ductal structures are usually normal.
  - Symptoms

        - Associated atresia or stenosis of the underlying duodenum.
        - Vomiting (may or may not be bilious) in newborns.
    - Diagnosis: upper gastrointestinal study.
    - Asymptomatic cases do not require treatment. For obstructive symptoms:
        - Use right upper quadrant transverse incision.
        - Perform side-to-side duodenoduodenostomy (transverse incision in proximal duodenum, longitudinal incision in distal duodenum), as in correction of duodenal atresia.
        - Alternately, perform duodenojejunostomy.
        - Avoid gastrojejunostomy.

Pancreatic Trauma

- Pancreatic trauma is often caused by blunt trauma (especially associated with impact with bicycle or motorcycle handlebars; the body of the pancreas may be transected when crushed over the anterior bodies of the lumbar spine).
- Diagnosis
    - Focused assessment with sonography for trauma (FAST) examination.
    - Computed tomography (CT) scan with oral and intravenous (IV) contrast.
    - Persistent elevation of amylase: magnetic resonance cholangiopancreatography (MRCP), or endoscopic retrograde cholangiopancreatography (ERCP) to rule out ductal injury (CT scan may be normal).
- Nonoperative management
    - Nonoperative management should be used when the patient is hemodynamically stable, transfusion requirement is less than 50% of estimated blood volume (ie, < 40 mL/kg) and there is no transection of the pancreatic duct.
    - Admit patient to a treatment facility.
    - Place patient under the care of a surgeon.
    - Ensure the operating room and personnel are immediately available.
    - Monitor serial hematocrit levels (initially every 4 hours).
    - Ensure there are adequate units of cross-matched blood available in the blood bank.

- Enforce bed rest for 48 hours.
- Restrict the patient's physical activity for 1 month.
- Perform an ultrasound based on clinical course and during follow-up for development of a pseudocyst.

- Operative management
  - Injury to the body of the pancreas or pancreatic duct requires drainage; even if a ductal injury is not identified, it should be presumed and drained using a closed drainage system.
  - Debride clearly nonviable tissue.
  - Treat transection or near-transection of the pancreatic duct.
    - Over sew or staple the distal end of the proximal pancreas.
    - Perform distal pancreatectomy (usually with splenectomy) if injury is in the tail.
    - Drain the distal segment of the pancreas by Roux-en-Y anastomosis to the jejunum.

Pancreatitis

- Alcohol and biliary tract disease, common causes of pancreatitis in adults, are uncommon in children.
- Pathophysiology is characterized by autodigestion (autolysis).
  - Exocrine enzymes are stored in inactive forms in protective zymogens.
  - The alkaline pH of exocrine glands and protease inhibitors provide protection.
  - Pancreatic injury (trauma, obstruction, inflammation) can rupture protective membranes within the gland and activate digestive enzymes, resulting in autodigestion.
- Symptoms: abdominal pain typically radiating to the back, and increased serum amylase.
- Diagnosis
  - A ratio of amylase to creatinine clearance greater than 6% indicates pancreatitis.

$$\frac{\text{urine amylase} \times \text{serum creatinine} \times 100}{\text{serum amylase} \times \text{urine creatinine}}$$

    - Laboratory tests: serum amylase and lipase.

        - Imaging methods: ultrasound, magnetic resonance cholangiopancreatography, and endoscopic retrograde cholangiopancreatography (contraindicated in acute pancreatitis).
- Etiology
    - The most common cause in children is blunt abdominal trauma.
    - The most common cause of nontraumatic pancreatitis is idiopathic.
    - Medications (eg, steroids, chemotherapy), infections, viral infections such as mumps, cystic fibrosis, underlying biliary tract disease, hemolytic disease resulting in stones (eg, spherocytosis, sickle cell disease), or cholelithiasis.
- Treatment
    - Medical
        - Discontinue offending medications.
        - Control infection.
        - Give nothing by mouth. Insert nasogastric tube if the patient is vomiting, administer total parenteral nutrition, and give analgesics (eg, meperidine, not morphine). Replace fluid volume.
        - Antibiotics, H2-blockers, and/or somatostatin are administered only if indicated for treatment of sepsis (antibiotics), or in severe/refractory cases.
        - Monitor arterial blood gasses for impending respiratory failure.
        - Monitor lactate dehydrogenase and serum glutamic oxaloacetic transaminase, which indicate tissue necrosis.
        - Monitor serum calcium for hypocalcemia (due to saponification); prescribe calcium gluconate as indicated.
        - Monitor serum glucose for hyperglycemia; prescribe insulin as indicated.
        - Monitor hematocrit for hemoconcentration or bleeding.
    - Surgical
        - Debride obviously necrotic tissue.
        - Drain (especially fluid in lesser sac).
        - Perform cholecystectomy for stones after resolution of the acute episode.

Pseudocysts

- Trauma is the most common etiology in children.
- Cyst walls are composed of inflammatory tissue (not epithelium) and are usually located in the lesser sac.
- Symptoms include pain, compression or erosion of surrounding organs, secondary infection, hemorrhage, and perforation.
- Diagnosis
  - Ultrasound.
  - CT with oral and IV contrast will show anterior and superior displacement of the stomach and downward colon displacement.
- Treatment
  - Medical
    - 50% of cases may resolve spontaneously in 3 to 4 weeks.
    - Endoscopic drainage.
    - Nothing by mouth.
    - Total parenteral nutrition.
  - Surgical
    - Surgery is indicated in the case of persistence (> 6 wk) or recurrence, and when pseudocyst communicates with a major duct.
    - Provide external drainage (if infected).
    - Provide internal drainage by Roux-en-Y cystenterostomy (unless the area is infected).
    - Perform distal pancreatectomy if pseudocyst is in tail.
    - Perform cystogastrostomy (open or endoscopic) if the pseudocyst is in the pancreatic body or adherent to the stomach (bleeding after operation is a common complication resulting from stomach acid).
    - Perform Roux-en-Y cystjejunostomy if the pseudocyst is located at the head of the pancreas or not adherent to the stomach.

Spleen

The thymus is the primary lymphatic organ during intrauterine life. The spleen is the major site of hematopoiesis from birth to 6 months of age, when hematopoiesis is taken over by the bone marrow. It produces immunoglobulin M (IgM) antibodies

against encapsulated bacteria (eg, pneumococcus, Haemophilus, meningococcus), and tuftsin and properdin, which enhance phagocytosis and stimulate production. Humoral immunity in neonates is transferred through the placenta (except immunoglobulin M).

Congenital Anomalies

- Asplenia (Ivemark syndrome) is the complete absence of the spleen. It is also called asplenia syndrome or heterotaxia. It can be associated with situs inversus (with or without malrotation or volvulus), cardiac anomalies (which are associated with a high mortality rate), and three-lobed lungs.
  - Symptoms include cyanotic heart disease, shortness of breath, and congestive heart failure.
  - Diagnosis
    - Howell-Jolly bodies present in a peripheral smear.
    - Ultrasound.
- Polysplenia
  - Multilobed spleen with 2 to 9 equal portions.
  - Associated with situs inversus, cardiac anomalies, and biliary atresia.
  - Normal splenic function.
- Accessory spleen
  - Small nodules of splenic tissue form apart from a normal-sized spleen.
  - Usually located in the splenic hilum (gastrosplenic ligament).
  - Nodules must be removed when a splenectomy is performed for hypersplenia to prevent persistent hematologic disease.
- Cysts
  - Congenital cysts are rare. Epidermoid cysts are the most common type in pediatric patients.
  - Symptoms: hemorrhage, left upper quadrant pain, and infection.
  - Echinococcal cysts: most common type worldwide.
  - Differential diagnosis is made by history, serology, and scan.
  - Diagnosis is confirmed with ultrasound, spleen scan, or CT scan.

- Treatment: partial cyst wall resection/marsupialization, rather than hemisplenectomy.

Trauma

- Diagnosis (see Pancreatic Trauma, above).
- Nonoperative management (see Pancreatic Trauma); patients who cannot be observed continuously in an intensive care unit or who will be evacuated through multiple levels of care are not candidates for conservative management.
- Indications for operative management include:
  - Transfusion requirement of more than 50% blood volume (~ 40 cc/kg).
  - Persistent hypotension despite volume resuscitation, or evidence of continued hemorrhage.
  - Associated significant injuries.
  - Abdominal distension and shock (immediate laparotomy is necessary).
- Treatment
  - Splenorrhaphy is often possible.
  - Perform splenectomy in an unstable patient with multiple injuries, one who will not be continuously observed in an intensive care unit setting, or one who will be transferred through multiple levels of medical care within 72 hours of operation.
  - Provide immunizations to protect against pneumococcus and vaccines to protect against *Haemophilus influenzae* and *Neisseria meningitidis*; give penicillin prophylaxis until the patient reaches 18 years of age.

Inflammation

- Acute inflammatory splenomegaly
  - Most commonly caused by infection.
  - Treat the source of infection (do not perform splenectomy).
- Abscess
  - Gram-negative anaerobic *Staphylococcus* is the most common cause of an abscess.
    - Hemoglobinopathy is associated with *Salmonella*.
    - Leukemia is associated with *Candida*.

- Other causes include:
  - trauma,
  - infarction,
  - bacteremia, and
  - immunosuppression.
- Symptoms include fever, left upper quadrant tenderness, and left shoulder pain.
- Diagnosis is made by ultrasound or CT scan (best modality).
- Treatment consists of IV antibiotics, percutaneous aspiration and drainage for large abscesses, and splenectomy (in the case of persistent infection).

Hematologic Disorders

- Red blood cells (RBCs)
  - Hereditary spherocytosis (autosomal dominant)
    - RBC membrane is abnormal, which prevents RBCs from assuming a discoid shape; deformity results in small, round, fragile RBCs.
    - Symptoms include anemia, jaundice, splenomegaly, and gallstones (gallstones occur in 75% of these patients).
    - Laboratory: anemia, increased bilirubin, increased reticulocyte count, spherocytes, and increased osmotic fragility.
    - Treatment: splenectomy (deferred until age 3–4 years; most common indication) and cholecystectomy if stones are present on preoperative ultrasound.
    - If hemolysis recurs or if no Howell-Jolly bodies are seen in a peripheral smear post-operatively, suspect residual accessory splenic tissue.
  - Elliptocytosis is rarely associated with RBC destruction sufficient to require splenectomy.
  - Sickle cell anemia
    - Homozygous sickle cell gene produces severe, chronic, hemolytic anemia.
    - Hemoglobin (HgB) levels in individuals with sickle cell anemia are as follows:
      - HgB S: 90%
      - HgB F: 5%
      - HgB A2: normal

        - HgB A: absent
    - Sickling results in occlusion of small vessels ("sickle cell crisis").
    - Etiology may include infection, dehydration, hypoxia, and acidosis.
    - Vaso-occlusive crisis is a potential complication characterized by stroke, pain and swelling in the hands and feet ("hand/foot syndrome"), acute abdominal pain, and pulmonary infarction.
    - Sequestration results in acute trapping of RBCs in the spleen, which leads to anemia, hypotension, and splenomegaly (if recurrent severe episodes [resulting in shock] occur, splenectomy is indicated after administration of polyvalent pneumococcal vaccine and *Haemophilus influenzae* type B vaccine).
    - Eventually the spleen becomes small, fibrotic, and infarcted (functional asplenia); the most common infections are pneumococcal and *Salmonella* osteomyelitis.
    - Laboratory indicators:
        - HgB: 6 to 8 g/dL.
        - Smear will show sickle, target, and nucleated RBCs; Howell-Jolly bodies; 5% to 15% reticulocytes; increased white blood count; and increased platelets.
        - Liver function tests will be abnormal.
        - Diagnosis in made by hemoglobin electrophoresis.
    - Treatment consists of hydration, packed red blood cell transfusion to decrease HgB S to less than 40% (20 cc/kg type-specific Rh[–] packed RBCs) from the usual 90%, and analgesics.
- White blood cells
    - Leukemia
        - Splenomegaly secondary to leukemic infiltrate is the most common cause of splenic rupture.
        - Splenectomy is not indicated.
    - Platelets
        - Idiopathic thrombocytopenic purpura (ITP): antiplatelet antibodies attach to platelets, making the platelets more susceptible to destruction in the spleen.
        - Spleen is normal-sized, platelets are normal shape.

- Usually occurs in children (especially females) under 10 years old, typically a few weeks after a mild viral illness.
- Symptoms: petechiae, bruising, and bleeding (worse if purpura is in the central nervous system).
- 75% of cases undergo spontaneous remission.
- Provide medical treatment for chronic or persistent ITP (see Chapter 32, Hematology and Oncology).
- Indications for splenectomy include the following:
  - an acute bleeding episode (especially in the central nervous system or intraabdominal space), and
  - failure of medical management.
- Splenectomy is curative in more than 90% of patients with ITP; however, if accessory splenic tissue is missed, symptoms may recur.
- If the platelet count is less than 50,000, platelet transfusion should be given only after the splenic artery is ligated, at which time the platelet count will start to rise.
- If postoperative thrombocytosis occurs (platelets number more than 1,000,000), prescribe aspirin.

- Hypersplenism
  - Pancytopenia (decreased white blood cells, RBCs, or platelets) may be primary or secondary to portal hypertension, inflammatory diseases, storage disease, chronic hemolytic disease, myeloproliferative disorder, or neoplastic disease.
  - Hypersplenism is associated with sickle cell crisis.
  - Treat primary hypersplenism with splenectomy; however, splenectomy is **not indicated** for secondary hypersplenism resulting from Hodgkin disease, sarcoid, leukemia, or portal hypertension.
- Wandering (ectopic) spleen
  - Anatomy: ligamentous attachments are absent, and the spleen is attached only by its hilar vessels; torsion may occur, leading to abdominal pain and possible splenic infarction.
  - Most common in male infants.
  - Diagnosis is made by ultrasound.
  - Treatment: splenopexy (if the spleen is not infarcted).
- Splenectomy

- The most common indication for splenectomy is ITP.
- Preoperative preparation
  - Immunize the patient with polyvalent capsular polysaccharide antigens of pneumococcal vaccine, ideally administered more than 3 weeks before elective splenectomy, and *Haemophilus influenzae* type B vaccine. Pneumococcal vaccine (pneumococcal polysaccharide vaccine [PSV23]) is only effective against 80% of organisms (it may be less effective in children younger than 2 y old) and provides protection for children 4 to 5 years old.
  - Administer prophylactic antibiotics before, during, and after operation, and prophylactically until the patient is 18 years old.
    - Use ampicillin in children under 10 years old.
    - Use penicillin if the patient is older than 10 years.
  - Administer an intraoperative stress dose of steroids (100 mg hydrocortisone IV) if the patient was treated with steroids immediately before the operation.
- Operative procedures
  - Place a nasogastric tube to prevent gastric distension and dislodgement of ties on the short gastric vessels.
  - Make a laparoscopic, upper midline, or left subcostal incision.
  - Mobilize by incising posterior, lateral peritoneal reflection.
  - Suture ligate and divide short gastric vessels.
  - Suture ligate and divide the splenic artery, then the splenic vein.
  - Avoid injury to the tail of the pancreas. If injury has occurred or is suspected to have occurred, closed drainage of the bed of the spleen should be performed.
  - Search for and resect accessory splenic tissue. All splenic tissue must be removed for hematologic reasons or the disorder will recur.
- Postoperative considerations
  - Sepsis: overwhelming postsplenectomy infection.
    - 50% mortality, especially in children under 2 years old.

- Risk is greatest in infancy, decreasing with age. The risk is twice as great in children younger than 2 years old, least when splenectomy is done for trauma, and greatest when splenectomy is done for thalassemia and other hematological indications.
- Incidence is approximately 5%, with 80% of infections occurring within 2 years of splenectomy.
- Symptoms are extremely rapid in onset and progression and include nausea and vomiting, confusion, seizures, shock, disseminated intravascular coagulation, and coma.
- The most common organism responsible is *Pneumococcus*.
- Prevent with polyvalent pneumococcal vaccine.

- Laboratory tests
  - Peripheral blood smear will show the following cytoplasmic inclusions: Heinz bodies, Howell-Jolly bodies, and siderocytes.
  - White blood cell count will be increased.
- Thrombocytosis
  - A platelet count less than 1,000,000 requires no treatment.
  - Platelet count may be greater than 1,000,000 10 days after operation; treat with aspirin (80 mg/day).
  - Thrombotic complications (eg, portal vein thrombosis, diagnosed by ultrasound) are rare.

Chapter 24

Genitourinary Tract

Introduction

The majority of pediatric patients with genitourinary trauma will have concomitant injuries (abdomen, thorax, spine, pelvis, femur). Managing genitourinary injuries in children is similar to management in adults. This chapter focuses primarily on the differences in management and also addresses some of the unique congenital and medical genitourinary conditions that may be encountered in pediatric patients.

Trauma

Renal Injuries

- Children are more susceptible to renal injury than adults due to thinner body habitus, less renal protection from the thorax, and less secure tissue attachments, resulting in higher mobility of the kidneys within the retroperitoneum.
- Preexisting renal anomalies (ureteropelvic junction [UPJ] obstruction, hydroureteronephrosis, horseshoe kidney) are 3 to 5 times more common in children undergoing evaluation for renal trauma than in adults.
- Children with preexisting renal anomalies frequently have hematuria out of proportion to the injury; however, the degree of injury is comparable to that in those without anomalies.
- Significant renal injury may be present in children without hematuria; up to 70% of children with grade 2 or higher renal injury will not have hematuria.
- Indications for renal imaging after abdominal trauma include:
  - Significant deceleration injury, such as
    - high-speed motor vehicle accident,
    - pedestrian struck by a car,

        - fall from greater than 15 ft, and
        - striking of flank with a foreign object.
    - Associated injuries, such as
        - fractures of the thoracic rib cage, spine, pelvis, or femur;
        - bruising of torso or perineum;
        - peritoneal signs; and
        - gross hematuria.
    - Microscopic hematuria with systolic blood pressure less than 90 mmHg at any time.
    - Any penetrating trauma.
- Imaging
    - Computed tomography (CT) scan
        - Stabilized patient: triphasic CT (scan precontrast, immediately following injection, and 15–20 min delayed).
        - Labile patient: single-phase CT immediately following injection will miss ureteral injury or urinary extravasations.
        - Severely unstable patients: intraoperative CT. Verify the presence of a functioning contralateral kidney prior to performing a trauma nephrectomy.
        - Obtain a single shot intravenous (IV) pyelogram using 2 mL/kg IV contrast; perform a radiograph of the kidneys, ureters, and bladder at 10 to 15 minutes.
    - Focused assessment with sonography for trauma (FAST) examination.
        - FAST provides 95% specificity, but only 33% to 89% sensitivity and only 50% negative predictive value.
        - FAST tends to detect only higher grade injuries and intraperitoneal fluid.
        - Use FAST sparingly if CT is available.
- Management
    - Determine grade of kidney injury.
    - Indications for nonsurgical management:
        - Patient is hemodynamically stable, grade 1 or 2, with or without associated abdominal injury.
        - Isolated grade 3 or 4, provided the distal ureter is intact.
        - A hemodynamically stable, grade 5 injury.
- Treatment

- Monitor patient on bed rest (urine output, vital signs) until the patient is able to ambulate from associated injuries and hematocrit has stabilized. There is no benefit from maintaining bed rest until hematuria clears.
- Perform serial physical examinations and hematocrit measurements.
- Clear guidelines for antibiotics use are not established.
  - Grade 1 to 3 injuries do not likely benefit from antibiotics.
  - In grade 4 to 5 injuries with urinary extravasation, consider antibiotics until the extravasation resolves.
  - Two to three days after injury, reimage (ultrasound or CT) grade 3, 4, and 5 injuries that were managed nonoperatively.
- Relative indications for operative intervention include:
  - persistent hemorrhage (consider embolization), and
  - extravasation of urine, progressive pain or ileus.
    - Consider a ureteral stent or percutaneous drainage of a urinoma, which will often successfully treat persistent urinary extravasation.
    - Pediatric ureteral stents, cystoscopic instrumentation, or fluoroscopy are frequently unavailable in an austere environment.
    - Within 2 weeks, 80% of urinary extravasation will resolve without intervention, even in grade 4 and 5 injuries.
- Absolute indications for operative intervention include:
  - hemodynamic instability due to a renal source,
  - expanding or pulsatile retroperitoneal hematoma,
  - unsuccessful attempt at angioinfarction,
  - coexisting abdominal injuries and grade 3 or greater renal injury (if expanding hematoma), and
  - an unstable patient with inadequate preoperative staging and a finding of retroperitoneal hematoma at exploration.
- Principles of renal exploration
  - Verify function of the contralateral kidney by pyelography before exploration.
  - Obtain control of the renal vessels prior to exploration.
  - Repair the renal injury.

- Hemostatic agents, such as GelFoam (Pfizer, Inc, New York, NY), Floseal (Baxter International, Inc, Deerfield, Ill), and Surgicel (Ethicon, Inc, Somerville, NJ) are useful adjuncts.
- V-Loc sutures (Coviden Inc, Dublin, Ireland) hold well in renal parenchyma.
- Close collecting system defects with fine absorbable suture (eg, 5-0 or 6-0 polydioxanone).
- Route drainage devices away from coexisting injuries.
- Separate intraabdominal and retroperitoneal injuries using omentum.

Ureteropelvic Junction Disruption

- CT scan findings include:
  - good renal contrast excretion with medial perirenal extravasation,
  - no parenchymal laceration, and
  - nonvisualization of ipsilateral ureter on delayed images (Figure 24-1).
- Treatment
  - Obtain a retrograde pyelogram to evaluate the extent of the UPJ disruption, if possible.
  - If the UPJ is intact and there is a renal parenchymal or pelvic laceration, place a ureteral stent; nephrostomy may be indicated. Consider Foley catheter drainage as well.
  - If the UPJ is disrupted and the problem is diagnosed **within 5 days**, perform immediate surgical repair.
    - Debride devitalized tissue.
    - Spatulate the ureter and connect it to the renal pelvis with fine, absorbable suture over a ureteral stent (5–6 French size [Fr]) or feeding tube.
    - Place an intraoperative nephrostomy tube if ureteral stent cannot be placed.
    - Place a retroperitoneal drain.
    - Mobilize the kidney for a tension-free anastomosis, if necessary.
    - If the UPJ is disrupted and problem is diagnosed **after 5 days**:

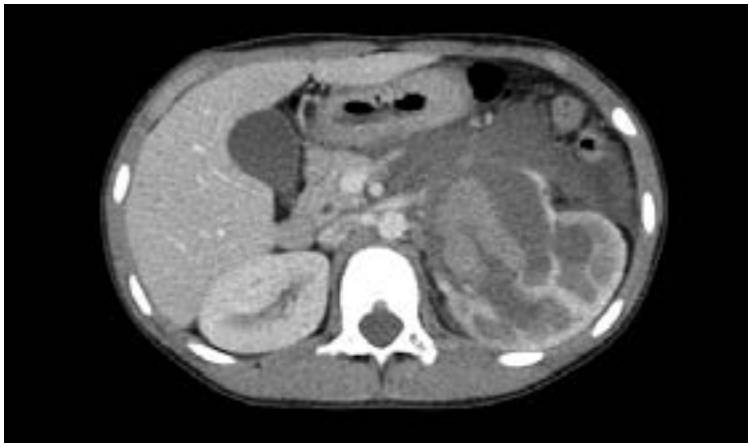


Figure 24-1. Ureteropelvic junction disruption. Note medial extravasation of contrast.

- ▹ Perform nephrostomy.
- ▹ Reassess after 12 weeks.
- ▹ Perform a retrograde pyelogram or CT urogram and functional imaging (MAG3 renal scan with Lasix [Sanofi SA, Paris, France] washout).

Ureteral Injury

- Ureteral injury accounts for less than 4% of penetrating injuries in children; it is extremely rare with blunt trauma.
- Its mortality rate of more than 30% is related to concomitant injuries.
- Two-thirds of cases do not have hematuria.
- High-velocity injury produces a blast effect.
- The ureter may appear intact at exploration.
- Delayed necrosis leads to urinary extravasation.
- Ureteral injury presents with urine output from surgical drains 3 to 5 days after injury, fevers, flank, or lower abdominal pain, or intestinal ileus.
- Management
  - ◦ Within 5 days of injury, perform a primary repair.

- Remove devitalized tissue.
- In general, spatulate and perform a tensionless anastomosis over a stent with a fine, absorbable suture (eg, 5-0 or 6-0 Vicryl [Ethicon, Inc, Somerville, NJ]).
- Mobilize the kidney or raise a bladder flap to relieve tension.
- In an unstable patient or in the presence of extensive injury, occlude the ureter with a large clip at the proximal end and place a nephrostomy tube or an externalized ureteral stent using a 5 or 8 Fr feeding tube and prepare for delayed repair.
- The type of repair will depend on level of the injury.
  - Istal ureter: ureteral reimplant with or without psoas hitch of bladder.
  - Mid ureter: ureteroureterostomy possible, possible psoas hitch and ureteral reimplant.
  - Extensive ureteral loss: proximal ureter ureteroureterostomy, ureteropyelostomy, Boari flap/transuretereroureterostomy/ureteral replacement (ileum).

Bladder Injury

- Bladder injury is frequently associated with multiorgan trauma and pelvic fractures.
- Absolute indications for surgical repair include:
  - all intra-peritoneal injuries, and
  - severe gross hematuria or clot retention and pelvic fracture with known extraperitoneal injury.
- Relative indications for surgical repair include:
  - persistent urinary extravasation despite adequate catheter drainage (extraperitoneal), and
  - large extraperitoneal injury in addition to presence of external pelvic fixation devices.

Bladder Neck Injury

- Image using cystogram (Figures 24-2 and 24-3).
  - Instill contrast agent at a volume of at least 1/2 of the estimated bladder capacity under gravity via urethral

catheter (bladder capacity in milliliters = [age + 2] × 30), or if under 1 year old (5–7 cc/kg). Refer to Table 24-1 for estimation of urethral catheter size.

- Standard cystogram
  - Abdominal plain film (scout).
  - Anterior-posterior (A-P) plain film and oblique after instillation of contrast.
  - Postcontrast drainage film.
- CT cystogram
  - Only requires fill film.
  - Dilute contrast to 1/4 to 1/3 of its full concentration using sterile saline.
  - Must fill bladder (not just clamp) catheter during contrast abdominal CT (fill per description above).

- Treatment
  - Administer antibiotics until 48 hours after the catheter is removed.

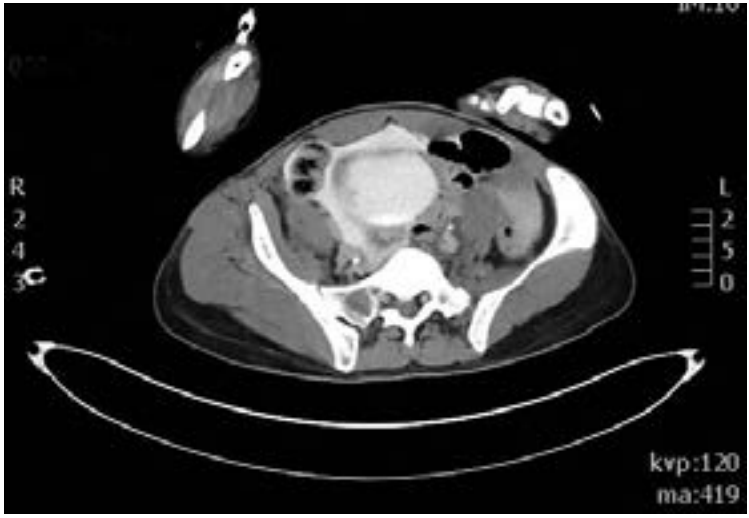


Figure 24-2. Computed tomography cystogram showing intraperitoneal bladder rupture.

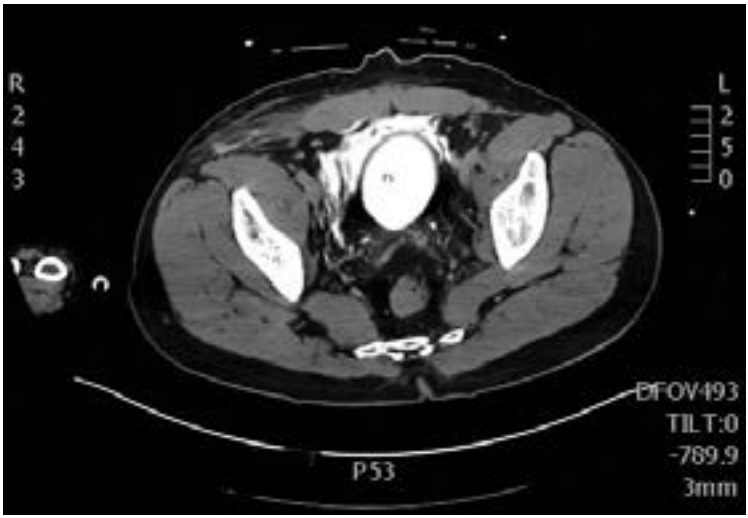


Figure 24-3. Computed tomography cystogram showing extraperitoneal bladder rupture.

Table 24-1. Urethral Catheter Size Estimation*

Age	Size†
Newborn	5
3 mo	8
1 y	8–10
3–6 y	10
8 y	10–12
10 y	12
12 y	12–14
Teenager	16+

*In males, use a tube that fits the meatus, the narrowest part of the male urethra.
†French feeding tube or Foley catheter. A French-sized feeding tube may be used if a Foley catheter is unavailable or if the Foley catheters that are available are too big.

- Small children, particularly boys, will need a large-caliber suprapubic tube (SPT); a small urethral catheter will not drain clots.
- Once repaired, drain 7 to 10 days, then reimage with a cystogram.
- If no bone spicules are evident and bladder neck injury is ruled out, place an indwelling catheter and observe extraperitoneal injuries; reimage in about 2 weeks.
- Identify and avoid disruption or occlusion of the ureteral orifices.
- Use absorbable suture in two-layer closure if possible, though one layer heals fine in almost every instance.
- Check for coexisting ureteral injury (ensure clear efflux if possible, consider IV methylene blue).
- Consider perivesical drain if closure was tenuous.
- Bladder injury is twice as likely to involve the bladder neck in children as it is in adults.
  - If bladder neck is not repaired, the patient will likely sustain persistent urinary extravasation.
  - Bladder neck injury increases the risk for incontinence.
  - Suspect a bladder neck injury if there is contrast extravasation and an incompetent bladder neck is apparent on cystogram.
- Repairing bladder neck injury
  - Open bladder at dome.
  - Use care to avoid disrupting a pelvic hematoma.
  - Use an intravesical closure (absorbable) suture in multiple layers with suprapubic and urethral catheter drainage.
  - Avoid iatrogenic injury to the ureters. Place temporary ureteral catheters (feeding tubes) if needed.
  - Close cystotomy per routine above.

Urethral Injury

- Urethral injury differs in children from that in adults.
  - Pelvic fracture is more likely to be unstable in children than in adults, displacing the prostatic urethra.
  - Complete posterior urethral disruption is more common in boys than men.

- There is a 20% incidence of both bladder and urethral injuries in children.
- Prepubertal girls are four-fold as likely to have urethral injury with a pelvic fracture as adult women.

- Imaging
  - Indications
    - perineal/penile hematoma,
    - blood at meatus/introitus,
    - inability to void,
    - one or more pubic rami factures **or** symphysis diastasis,
    - evidence of bladder neck injury on CT, and
    - inability to pass a urethral catheter.
      - Males: Perform retrograde urethrogram. Insert a 6 Fr or 8 Fr Foley catheter, with balloon gently inflated with approximately 1 cc, in the fossa navicularis and perform retrograde instillation of 10 to 15 cc contrast with an oblique film, visualizing contrast into the bladder.
      - Females: Anesthetize patient and perform vaginoscopy or cystoscopy. For prepubertal girls, use a nasal speculum, cystoscope, or ureteroscope.
  - Urethral injury combined with pelvic fracture mandates a rectal examination.
    - Blood in stool indicates a potential occult rectal injury.
    - Consider rigid proctoscopy. Rigid scopes are the standard of care in trauma because of their ease of use in an unprepped patient, availability, and speed, and because they do not require a high-intensity light source.
    - Treat the rectal injury with a sigmoid colostomy.
  - Urethral injury in boys is frequently associated with a pelvic fracture. Most are bulbomembranous urethral disruptions but prostatic urethral disruption from the bladder neck can occur in young boys with severe trauma.
    - Perform a retrograde urethrogram (RUG) by inserting a 6 Fr or 8 Fr Foley catheter, with the balloon gently inflated with approximately 1 cc, into the fossa navicularis and perform retrograde instillation of 10 to 15 cc of water-soluble contrast and obtain an oblique film, visualizing the flow of contrast in the urethra and bladder.

- If RUG demonstrates the presence of, or is suspicious for, a complete urethral disruption, then:
  - Divert urine per below and prepare for delayed repair in 3 to 6 months.
  - Immediate repair is associated with worse outcomes with respect to stricture, erectile dysfunction, and incontinence.
- Injuries to the anterior urethra can be repaired primarily in the absence of large amounts of devitalized tissue. With blast injuries and massive tissue loss, debride and divert urine and plan for delayed reconstruction.

- Urethral injury in girls
  - Invariably associated with a pelvic fracture.
  - 75% are associated with a vaginal injury, 30% are concurrent with rectal injury.
  - Treatment
    - Administer broad-spectrum antibiotics.
    - Assess bladder neck.
    - Establish urinary drainage with a urethral catheter or SPT; vesicostomy is a diversion option in infants and small children. Make a small transverse incision between the pubis and the umbilicus, mobilize and open the dome of the bladder, and mature stoma (evert and sew down along the edge of the bowel) to rectus fascia and skin.
    - Encourage gentle passage of urethral catheter (if disruption is not complete) to establish continuity; abort if passing the catheter is difficult.
    - If the urethra is repaired or a catheter is placed across an incomplete urethral disruption, leave the catheter in place for 3 weeks then perform a pericatheter RUG or voiding cystourethrogram prior to catheter removal.
    - Repair small lacerations of the anterior urethra with fine, absorbable suture in multiple, nonoverlapping layers, if possible.
    - If there is a large injury or complete disruption, close likely vaginal laceration and divert urine for delayed reconstruction of urethra.

External Genital Injuries

- Management of penile, scrotal, and testicular injuries is equivalent to that of adults.
- Evaluate for concomitant rectal injury in the presence of penetrating scrotal or vulvar trauma.
- Perform meticulous examination under anesthesia to assess depth and extent of the wound, debridement of nonviable tissue, and evidence of concomitant injuries.
  - Even the smallest penetrating blast wound on the scrotum can be associated with testicular rupture; there is a low threshold to explore surgically if physical examination is not completely normal.
  - Scrotal ultrasound can be useful in helping decide on the need for surgical exploration.
- In the presence of associated hematuria or blood on rectal examination, evaluate for urethral injury or rectal injury, respectively.
- Repair injuries with appropriately sized fine absorbable suture.
- If there are concerns for nonviable tissue, debride on multiple occasions prior to considering reconstruction.
- Meticulous closure of the tunica albuginea of the testis in the presence of testis rupture is important; doing so may reduce inflammation and the production of antisperm antibodies, which can affect future fertility.

Conditions of the Genitourinary Tract

Urinary Tract Infection

- Diagnosis
  - Neonates: symptoms include jaundice, failure to thrive, and fever.
  - Older children: symptoms include dysuria, urgency, frequency, enuresis.
  - A positive urine culture using urine taken from a collecting bag should be confirmed by a specimen obtained by suprapubic aspiration or sterile transurethral catheterization. Urinary tract infection (UTI) manifests as more than 10^5 colonies/mL of a single bacterial species.

- Accuracy is 80% in a bagged specimen, 95% in a catheterized specimen, and 99% in a specimen obtained from suprapubic aspiration.
  - White blood cells in urine are suggestive of UTI (usually leukocyte esterase positive).
  - Perform a nitrite test. Nitrate that is normally present in urine is converted to nitrite by bacteria.
- Classification
  - Upper tract infection (pyelonephritis)
    - Symptoms: fever, flank pain or tenderness, increased white blood cell count.
    - Imaging: ultrasound/CT scan to rule out a perinephric abscess.
    - Treatment: IV antibiotics for at least 14 days.
  - Lower tract infection: diagnosis is made by suprapubic aspiration or catheterized specimen.
- Pathophysiology
  - Protective factors include:
    - regular complete bladder emptying (avoid urine stasis),
    - antimicrobial activity of urothelium (urothelial cells secrete a mucopolysaccharide coating, which traps bacteria), and
    - acid pH and high urinary osmolality.
  - Potentiating factors include urinary stasis, vesicoureteral reflux, urolithiasis, obstruction, periurethral colonization (usually with gut flora), and phimosis.
  - Bacterial factors
    - O (lipopolysaccharide), K, H antigens;
    - hemolysins; and
    - urease produces alkalization of urine, resulting in stone formation.
- Laboratory findings
  - 50% of patients under 12 years old with a UTI have associated urinary tract abnormalities.
  - If a culture from urinary analysis is positive, proceed to renal and bladder ultrasound, especially if UTI is associated with fevers.
  - If patient has had multiple UTI episodes or ultrasound is abnormal, consider voiding cystourethrogram.

        - Nuclear medicine studies, such as a dimercaptosuccinic acid renal scan, are in the algorithm for febrile UTI work-up in children, but this modality is not likely to be available in an austere environment.
    - Treatment
        - Multidrug-resistant organisms can be highly prevalent even in austere environments (eg, there is a high prevalence of extended spectrum beta-lactamase multidrug resistant *E coli* in Afghanistan).
            - If antimicrobial resistance profiles are available for your area, chose therapies accordingly.
            - Use ampicillin plus gentamicin for the majority of gram-negative organisms, third- or fourth-generation cephalosporin, extended spectrum penicillin for 10 to 14 days.
        - Provide adequate hydration.
        - Consider Foley catheter drainage during the acute phase of infection.
        - Consider drainage of any potentially obstructed regions of the urinary tract (SPT or Foley catheter for bladder outlet obstruction, percutaneous nephrostomy or ureteral stent for upper tract obstruction).

Penis

- Foreskin retractility
    - In a term newborn, the foreskin is usually not retractile (physiologic phimosis). At 6 months old, it is about 20% retractile; by 6 years old, it is 40% retractile; and by 13 years old, it is 100% retractile.
    - High-potency steroid ointments (eg, clobetasol or betamethasone 0.05%) applied twice a day for 6 weeks, along with manual retraction, can resolve clinically significant phimosis in lieu of circumcision.
- Hypospadias
    - Hypospadias describes the condition when the urethral meatus opens onto the ventral surface of the penis, proximal to the end of the glans.
    - Associated anomalies include inguinal hernia and undescended testicles (UDTs), disorders of sexual differentiation.

- Hypospadias is usually repaired in the first year of life.
- Hypospadias commonly involves the distal penis (glanular or coronal).
- It may be associated with ventral curvature (ie, chordee).
- Avoid circumcision to facilitate later reconstruction, if desired.
- Distal hypospadias without chordee does not generally affect voiding or fertility and does not need repair, especially in an austere environment.
- Repair of more proximal hypospadias should be performed by a surgeon with advanced training in pediatric genital reconstruction because of the risk of potential complications.

- Epispadias
  - Epispadias describes the condition in which the urethral meatus opens onto the dorsal surface of the penis, proximal to the end of the glans (Figure 24-4).
  - It is usually also associated with bladder exstrophy.
  - Repairing bladder exstrophy or epispadias is a major undertaking.
    - In developing countries, exstrophy and epispadias are often either not repaired or are addressed with some form of urinary diversion (cystectomy, ureterosigmoidostomy).
    - Bladder closure usually requires osteotomy with prolonged hospitalization and is not advisable in an austere environment.
    - Isolated epispadias is rare but can be repaired on an outpatient basis.
- Phimosis
  - Phimosis manifests on physical examination when the male foreskin cannot be fully retracted behind the head of the penis (this normal in infancy; Figure 24-5).
  - It is congenital or acquired secondary to recurrent infections of the glans penis (balanitis) or foreskin (posthitis), or following local trauma.
  - Complications include impairment or obstruction to urinary flow with ballooning of the foreskin upon voiding and paraphimosis.
  - Treatment is circumcision or a 6-week trial of high-potency steroid ointment (betamethasone 0.05% or clobetasol 0.05%



Figure 24-4. Bladder exstrophy with epispadias.



Figure 24-5. Phimosis.

ointment) applied twice a day with manual retraction of foreskin (over 80% success rate).

- Paraphimosis
  - Paraphimosis is evident on physical examination when the foreskin becomes trapped behind the glans penis and cannot easily be pulled back to its normal position. This is usually associated with remarkable edema of the foreskin and glans by the time of presentation (Figure 24-6).
  - Complications include constriction of blood supply to the glans.
  - Treatment options
    - Compress the glans and move the foreskin back to its normal position. This can almost always be done but requires very aggressive compression of the glans and foreskin and may require at least conscious sedation.
    - Make a dorsal slit in the foreskin or perform circumcision.



Figure 24-6. Paraphimosis.

        - Under topical (lidocaine/prilocaine cream) or regional anesthesia (penile block), use a syringe needle to make multiple punctures in the edematous foreskin, express the edema fluid, then compress as described above.
    - To prevent recurring paraphimosis, pull the foreskin back over the glans after it has been retracted (eg, for insertion of a Foley catheter).
- Circumcision
    - Surgical indications for circumcision include:
        - Definite: phimosis that is not responsive to medical therapy (steroid ointment), paraphimosis, and recurrent balanitis.
        - Relative: recurrent UTI (may only reduce infection risk in the first year of life).
    - Techniques (YouTube videos are very instructive for those unfamiliar with the use of any of these devices):
        - Freehand using sleeve technique.
        - PlastiBell (Hollister, Inc, Libertyville, Ill).
        - Gomco clamp.
        - Mogen clamp.
    - Complications include bleeding, infection, urethral injury, and removal of too much or too little foreskin.

Testicular and Scrotal Conditions

- Retractile testis
    - In a term male infant, both testes are normally present within the scrotum.
    - A retractile testes appears to be undescended and can be brought down into the scrotum by careful manipulation, and will remain there when the child is calm.
    - Retractile testes are usually bilateral and result from an overactive cremaster muscle, which becomes less active with age.
    - Testes normally remain in the scrotum after the onset of puberty.
- Cryptorchidism
    - In **ectopic** cryptorchidism, the testis is located in an abnormal position (thigh, groin). This results from abnormally positioned gubernaculum and puts the patient at an increased risk of trauma.

- Anorchism/Vanishing Testis
  - Anorchism: testis is absent due to prenatal torsion or infarction.
  - Diagnose with laparoscopy and groin exploration. Do not rely on ultrasound findings.
  - Bilateral anorchism: requires a lifetime of endocrine support at expected onset of puberty.
- An undescended testicle (UDT) is associated with abnormal spermatogenesis and an increased risk for future development of testicular cancer. The higher the position of the testis, the more abnormal, and the more difficult to reposition into the scrotum. In most cases, the testis fails to reach scrotum because the gonadal artery is too short. UDT may be located anywhere from the renal hilum to the external inguinal ring.
  - Smaller, softer, and more elongated than a normal testes.
  - 80% to 90% have an associated hernia sac.
  - Testicular degeneration begins after the second year of age.
  - May produce autoantibodies that injure the other testis.
  - Incidence (similar to inguinal hernias)
    - Right side: 50%.
    - Left side: 25%.
    - Bilateral: 25%.
    - 10-fold more common in premature infants.
    - About 4% of full-term newborn male infants will have a UDT.
    - About 75% will descend in the first 6 months of life such that about 0.8% to 1% of males beyond 6 months of life have a UDT.
  - Operation is indicated for the following reasons:
    - Improved spermatogenesis. Cryptorchid testis is exposed to increased temperature, resulting in decreased spermatogenesis. Determinants of the degree of testicular damage include length of exposure and degree of nondescent.
    - Unilateral UDT, which is associated with approximately normal fertility if corrected before 2 years of age.

- Potential for malignant change, which results in 10- to 20-fold increased risk for testis cancer if it is not corrected. The sooner the testis is positioned into the scrotum, the more the risk for cancer is reduced. Risk is not completely absolved with orchiopexy, but detection is much easier if testis is in scrotum.
- Decreasing the high possibility of trauma and torsion in UDT.
- For repair of associated hernia.
- For cosmetic and psychological considerations.

- Perform an orchiopexy by 6 months to 2 years of age. Orchiopexy in older children is possible and indicated, but outcomes are poorer. Beyond approximately 14 years of age, orchiectomy with orchiopexy of the contralateral testis is usually recommended, provided contralateral testis is normal.
  - To treat surgically, free the testis and spermatic cord structures from the attached cremasteric fibers and place into a dartos pouch within the scrotum. The length of the gonadal artery may be a limiting factor. If testis is not palpable, first perform a diagnostic laparoscopy, if possible.
  - When testis are found to be intraabdominal, use first-stage Fowler-Stephens orchiopexy (laparoscopic). Ligate (clip) the spermatic artery and vein high in the retroperitoneal space; the testicular blood supply is then derived from vessels to the vas, deep epigastric collaterals, and processes vaginalis. Second stage Fowler- Stephens can be performed at 6 to 12 months after the first stage by bringing the testicle down into the scrotum (usually laparoscopically) on its new collateral blood supply.
  - Single-stage laparoscopic orchiopexy without vessel ligation can sometimes be performed.
  - Single-stage Fowler-Stephens orchiopexy is also an option with higher risk of postoperative testis atrophy.
  - Testes absent ("anorchia" or "vanishing"): diagnose by identifying a blind-ending vas and vessels (using laparoscopy), then close.

        - Atrophic/dystrophic testes: orchiectomy, especially if contralateral testis is normal.
        - Vas and vessels exiting internal ring: perform groin exploration and orchiopexy (less likely) or orchiectomy (most likely). Usually an atrophic scrotal "nubbin" can be found in this instance.
        - Testis palpable in canal: perform orchiopexy.
        - Results include injury to vas (uncommon); injury to gonadal vessels, which may cause atrophy; invariably infertility in patients with uncorrected bilateral UDT (70% of patients with bilateral UDT corrected prior to 2 years of age are fertile).

Acute Conditions of the Scrotum

- Torsion
  - Torsion is the most common genitourinary emergency of childhood.
  - It usually occurs in late childhood to early adolescence, peaking at age 14, but can occur at any age.
  - Torsion is the twisting of the testicle on its blood supply, which may result in infarction.
  - Differential diagnosis
    - Major
      - Torsion of testis.
      - Torsion of appendix testis or epididymis.
      - Epididymitis.
      - Orchitis.
      - Trauma.
      - Tumor.
      - Hemorrhage.
    - Minor
      - Idiopathic scrotal edema.
      - Hernia/hydrocele.
  - Types of torsion
    - Neonatal torsion/extravaginal
      - Occurs in the perinatal period due to poor fixation of the tunica vaginalis to the overlying dartos.
      - True torsion of the spermatic cord.

- Usually results in complete infarction by the time of presentation, requiring orchiectomy.
- Probable etiology of "vanishing testis" syndrome (unilateral anorchia).
- Need for contralateral orchiopexy to prevent metachronous torsion is controversial, but probably not harmful.

- Intravaginal or bell clapper deformity
  - Abnormally high reflection of the tunica vaginalis upward from its usual, more equatorial position about the testicle to a level of attachment to the spermatic cord itself.
  - Leaves the testicle hanging (like the clapper of a bell) within the tunica vaginalis, able to spin freely around the long axis of the spermatic cord.
- Typical adolescent torsion.

- Symptoms of torsion
  - Scrotal pain
    - Abrupt onset suggests testicular torsion; acute scrotal pain must be considered torsion of the testicle until proven otherwise.
    - Gradual (12–24 h) onset suggests torsion of the appendix testis or infectious case; pain radiates upward toward groin and lower abdomen.
    - Nausea and vomiting are predictive of testicular torsion and the absence of these symptoms makes torsion less likely; lower abdominal pain can also be present.
    - History will consist of prior transient episodes of testicular pain with spontaneous resolution (intermittent torsion).
    - Will present with red, painful, tender scrotum; testis will be enlarged, tender, and elevated within scrotum.
    - Pain is increased (or not decreased) when scrotum is lifted (negative Prehn's sign).
    - Differential diagnosis: localization of tenderness to particular scrotal structures.
- Laboratory tests
  - Complete blood count may show increased white blood cell count.

        - Urinary analysis will show increased white blood cell count.
        - Diagnose using Doppler ultrasound to assess blood flow to the testicle and differentiate ischemia (torsion) from an inflammatory process (epididymitis). Epididymitis and torsion of appendix testis will show markedly increased blood flow to the affected side.
    - Treatment
        - Sedate the patient and attempt manual detorsion.
            - Torsion will usually (but not always) occur in a medial direction.
            - Detorsion should be attempted by twisting the testicle laterally (like opening a book).
            - Even if detorsion is successful, immediate orchiopexy is still recommended. Perform prompt bilateral orchiopexy using midline scrotal raphe incision. Detorse testis and assess viability (cover in warm soaked gauze and assess with Doppler, if needed). If viable, suture tunica albuginea to scrotal wall using 3 to 4 nonabsorbable or long-lasting absorbable sutures. If torsion is present for more than 12 hours or is necrotic, consider performing orchiectomy (necrotic testes may produce autoimmune antibodies). **DO NOT** forget to perform orchiopexy on the contralateral testis, regardless of the outcome of the affected testis. If torsion is present at birth, stabilize the baby before exploration (salvage is rarely possible).
    - Prognosis
        - Patient will have an increased risk of impaired spermatogenesis and infertility.
            - Up to 6 hours: 90% chance of salvage.
            - 6–12 hours: 75% chance of salvage.
            - 12–24 hours: 50% chance of salvage.
            - Over 24 hours: less than 10% chance of salvage.
- Torsion of appendix testis or appendix epididymis
    - Transillumination may reveal the "blue dot" sign.
    - Treatment
        - Keep patient on bed rest with scrotal support and provide analgesics.

    - Operative intervention is rarely needed unless severe symptoms persist more than 2 to 3 days.
    - If torsion of the testis cannot be distinguished from appendix testis by physical examination or Doppler ultrasound, prompt surgical exploration is indicated.
- Epididymitis
  - Epididymitis is reflux of urine from the vas to the epididymis, inciting an inflammatory response, usually due to excessive urine holding or dysfunctional voiding. It can also be a result of a sexually transmitted disease (usually *Neisseria gonorrhoeae* or *Chlamydia trachomatis*). Viral syndromes are also possible.
  - Symptoms
    - Pain is decreased when the scrotum is lifted (Prehn's sign).
    - Urinary tract symptoms associated with epididymitis (usually seen in postpubertal boys) include urinary frequency, dysuria, and pyuria.
  - Diagnosis and laboratory tests
    - Urinary analysis will reveal bacteria.
    - Send urine for culture, if possible.
    - Test for sexually transmitted diseases in sexually active males.
    - If urine culture is positive in a nonsexually active male, rule out congenital urinary tract anomaly (meatal stenosis, urethral stricture, delayed presentation of posterior urethral valves, etc).
    - In recurrent cases, perform renal ultrasound to rule out hydronephrosis. Screen for ureteral ectopia.
    - Consider performing voiding cystourethrography to rule out bladder outlet obstruction in recurrent cases.
    - Noninvasive urinary flow testing (flow-rate) is also helpful, if available.
  - Treatment
    - If patient is sexually active, give antibiotics for chlamydia (doxycycline or azithromycin).
    - If patient is not sexually active, give fluoroquinolone (short courses are sufficient in children), oral cephalosporin, or sulfamethoxazole/trimethoprim for 14 days.
    - Use analgesics.

- Orchitis
  - Orchitis is usually due to a viral infection (eg, mumps).
  - Scrotal skin is erythematous and edematous on physical examination, white blood cell count is increased, urinary analysis is normal, and ultrasound shows good blood flow to testis.
  - Treatment consists of bed rest and observation.
  - Orchitis is associated with decreased fertility.
- Varicocele
  - Varicoceles occur most commonly on the left (left spermatic vein drains into the left renal vein).
  - When idiopathic, they result from incompetent venous valves. They can often occur due to renal vein obstruction (renal vein thrombosis, retroperitoneal tumor; suspect obstruction in right-sided varicoceles).
  - Symptoms include pain, testicular atrophy or hypotrophy, and decreased fertility (due to increased ambient temperature).
  - Diagnosis is made by physical examination and confirmed with ultrasound, which will show dilated veins ("bag of worms") superior to testis that increase with Valsalva maneuver and decrease when patient is supine.
  - Treatment
    - Measure dimensions of the testicle; atrophy more than 20% compared to contralateral testis and pain are the primary indications for operation.
    - If there is no significant atrophy and no pain, observe the patient.
    - Perform laparoscopic, retroperitoneal ligation of the spermatic veins and artery, or inguinal or subinguinal varicocele ligation; all approaches are viable and effective.
- Tumor
  - The most common testicular tumors in childhood include teratomas, yolk sac tumors, rhabdomyosarcoma, and lymphoma.
  - A solid scrotal mass will be evident on physical examination.
  - Diagnosis is made by ultrasound; elevated serum levels of α-fetoprotein, β-human chorionic gonadotropin,

lactate dehydrogenase; or visible mass lesion on the CT of abdomen and pelvis, if available.

- Treatment consists of radical orchiectomy.
  - Use inguinal incision; never approach through a scrotal incision.
  - Do not perform a percutaneous biopsy.
  - Clamp and individually ligate cord structures at the internal ring.
  - Deliver testicle.
  - Perform high inguinal orchiectomy if a neoplasm is present.
  - The most common tumors (yolk sac and teratoma) usually have a benign course in prepubescent children and orchiectomy is curative.
  - If patient is an adolescent child going through puberty, treat as though the patient were an adult.
  - The need for adjuvant therapy is based on pathology results, tumor marker response, and axial imaging.
- Renal tumors
  - Treat and cure congenital mesoblastic nephroma in newborns with nephrectomy.
  - Wilms tumor occurs most commonly in 3- to 4-year-olds.
    - Usually presents as a palpable flank mass or gross hematuria.
    - Diagnose using ultrasound or CT scan.
    - Staging and decision of surgical versus chemotherapy is complicated and should be researched prior to deciding on a treatment plan.
    - General US practice is to perform initial radical nephroureterectomy with lymph node biopsy for lower stage tumors.
  - Clear cell sarcoma of the kidney and renal cell carcinoma usually result in poor prognosis in older children. Consider whether definitive pathology results will be available before performing surgery for suspected malignancy. If you do not have access to pathology services but the patient can be transferred to a treatment facility where these services are available, it is often better to leave the tumor in the patient for excision at

the receiving facility rather than risk losing the specimen in transit. Pathology results are critical in determining follow-up care and surveillance regimens.

Vaginal Conditions

- Labial fusion (labial adhesions)
  - Etiology: chronic irritation, lack of estrogen stimulation.
  - Symptoms include difficulty urinating, UTI, and pain.
  - Physical examination will show fused labia minora.
  - Treat as follows:
    - Perform incision or separation under general anesthesia.
    - Prescribe topical estrogen cream and/or high potency steroid ointment twice a day for 14 days.
    - Perform gentle separation in office after applying lidocaine jelly or lidocaine/prilocaine cream.
  - To prevent labial fusion, the patient must maintain good hygiene. Liberally apply petroleum jelly after separation for several weeks to prevent recurrence.
- Vaginitis
  - Etiology
    - When the patient is in prepuberty, allergy or irritation due to bubble bath or laundry detergent is most common, poor hygiene is also very common. Vaginal voiding with chemical irritation from urine is another potential cause.
    - When the patient has reached puberty, the most likely cause is infection.
    - Ensure child has not been abused.
    - Foreign body may also be to blame.
  - Diagnosis using vaginoscopy.
  - Treatment
    - Remove foreign body or irritant.
    - Give antibiotics for infection (consider antifungals).
    - Recommend sitz baths and improved hygiene.
    - Change voiding behavior to prevent vaginal contamination (legs far apart, rock pelvis forward, or sit on toilet backwards).
- Urolithiasis

- In the austere environment and in developing countries, renal and bladder stones are extremely common in both adults and children.
- Stones are a significant source of pain, UTI, and progressive renal failure.
- Urolithiasis is due to a poor, grain-based diet; overly prolonged breast-feeding; and generalized dehydration. Check serum calcium and uric acid, and perform a stone analysis.
- Endoscopic management of urolithiasis is very dependent on advanced urologic instrumentation and best left to a surgeon with specific urologic training.
- Bladder stones are easily treated with an open cystotomy incision, stone removal, and bladder closure.
  - Leave an indwelling catheter (Foley or SPT) in place for 7 to 10 days.
  - Close bladder in 2 or 3 layers using absorbable suture.
- Renal stones can be treated with open pyelolithotomy or anatrophic nephrolithotomy.
  - If open stone surgery is performed, leaving a percutaneous nephrostomy tube or indwelling ureteral stent is recommended if possible, with removal in 7 to 10 days to decrease the risk of urine leak and urinoma.
  - Decrease warm ischemia with iced saline slush (if available) when performing anatrophic nephrolithotomy.
  - Poorly functioning kidneys filled with stones are best treated with nephrectomy, especially when the contralateral kidney is normal.
  - Advanced reading on the surgical steps is recommended prior to proceeding with open stone surgery, as most surgeons rarely perform these procedures even outside of an austere environment.

Medicine

Chapter 25

Basic Fluid and Electrolytes

Introduction

Infants and young children have a greater need for water and are more vulnerable to alterations in fluid and electrolyte imbalances than adults. Water and electrolyte imbalances occur more frequently and more rapidly in children. In addition, children adjust less promptly to those disturbances because infants and children also have a greater proportional amount of extracellular fluid volume.

Normal Distribution of Body Water and Electrolytes

Total body water (TBW) varies with an individual's age and amount of muscle mass and body fat.

- 80%–85% of a premature infant's body weight is attributed to water.
- About 70% of a full-term infant's body weight is attributed to water.
- Body weight attributed to water in young adults differs between males and females:
  - Males: approximately 65% total body weight.
  - Females: approximately 52% of total body weight.
- During infancy, a larger proportion of body water is extracellular.

Changes in Fluid Composition and Distribution During Critical Illness

Critically ill infants and children tend to retain fluids because of increased secretion of antidiuretic hormone (ADH) and aldosterone.

- Catecholamine release, hypotension, fright, and pain stimulate the release of ADH, renin, and aldosterone.
- ADH release is also stimulated by any condition that reduces left atrial pressure (eg, hemorrhage, positive-pressure ventilation, or severe pulmonary hypertension), general anesthetics, morphine, and barbiturates.
- Critically ill pediatric patients often exhibit decreased urine volume and increased urine concentration in the presence of dilution of intravascular space.
- A newborn's kidney has a limited ability to concentrate urine (< 600 mOsm/L); a neonate may have decreased urine volume and only moderate urine concentration.

Table 25-1. Pediatric Daily Maintenance Fluid Requirements

Age/Weight	Fluid	Goal Calories (kcal/kg)	Dextrose*
Infants (> 1 month old)	100–120 mL/kg	~ 120	5%–10%
< 10 kg	100 mL/kg	~ 110	5%
10–20 kg	1,000 mL + 50 mL/kg > 10 kg	~ 80	5%
> 20 kg	1,500 mL + 20 mL/kg > 20	≥ 45	5%

*Percent of dextrose in water.

Administering Maintenance Fluid

Fluid administration must be tailored to prevent fluid overload or sodium imbalance (Tables 25-1 and 25-2).

- Fluid and electrolyte losses in urine most closely resemble 0.45 normal saline (½NS); insensible losses are more similar to 0.2 NS.
- Daily sodium requirement: 3 mEq/kg/day.
- ½NS is usually administered with 5% or 10% glucose immediately postoperatively to replace insensible and urine losses.
- Excessive gastrointestinal losses are generally replaced with ½NS or NS.

Table 25-2. Pediatric Daily Electrolyte Requirements*

Age	Sodium	Potassium	Magnesium†	Calcium†	Phosphorus†
Infants/Children	3.0 mEq/kg‡	2.0 mEq/kg	0.25 mEq/kg	1.0 mEq/kg	0.50 mEq/kg
Adolescents	2.0 mEq/kg	1.0 mEq/kg	0.25 mEq/kg	0.25 mEq/kg	0.25 mEq/kg

*A standard pediatric fluid is D_5 ½NS with 20 mEq of KCl. (Some experts now recommend using normal saline as a base intravenous fluid in pediatrics to avoid iatrogenic hyponatremia.)
†Consider adding if using intravenous fluids for more than 3 to 5 days.
‡1 mEq potassium phosphate = 0.68 mMol phosphorus (1 mEq sodium phosphate = 0.75 mMol phosphorus).

Table 25-3. Differentiating Sources of Sodium Disturbances

Condition	Intravascular Volume Status	Serum Sodium	Urine Volume	Urine Sodium	Net Sodium Status
Hyponatremic dehydration	↓	↓	↓	↓	↓
SIADH	Normal or ↑	↓	↓	↑	Normal
CSW	↓	↓	↑	↑	↓

↓: decreased
↑: increased
CSW: cerebral salt wasting
SIADH: syndrome of inappropriate antidiuretic hormone

- All infusions should be connected to a constant infusion pump.
- Specific electrolyte needs and therapies require different concentrations.
  - D_{10} with ½NS: neonates; D_5 with ½NS: older infants and children.
  - Add potassium (20 mEq/L) if urine output is adequate, or if serum creatinine and potassium levels are normal.
  - Some experts now recommend using NS as a base intravenous (IV) fluid in pediatrics to avoid iatrogenic hyponatremia.
  - Monitor urine volume closely, using a Foley catheter if necessary.
    - The average is greater than 1 mL/kg/h if fluid volume is adequate.
    - If fluid is severely restricted, urine volume may average 0.5 to 1 mL/kg/h.
- Fluid deficit replacement can be calculated using the following formula:

% deficit × weight (grams) = fluid deficit in mL

For example, 10% dehydration of a 7-kg infant would be calculated as follows:

10% × 7,000 g = 700 g or 700 mL

Add deficit to maintenance fluids of 700 mL to give 1,400 mL for the day.

- See Chapter 6, Hemodynamics and Shock, Table 6-1, for clinical features to help assess the severity of hypovolemic shock.
- To calculate hourly maintenance fluid rate, give 4 mL/kg/h for the first 10 kg body weight, an additional 2 mL/kg/h for the second 10 kg body weight, and 1 mL/kg/h for every kg above 20 kg.

Electrolyte Management

Hypokalemia

- Commonly seen with use of loop and thiazide diuretics.
- Also found following vomiting, diarrhea, intestinal fistulas, ileostomy drainage, or gastric suctioning.
- Excessive renal excretion of potassium is associated with metabolic alkalosis, renal tubular acidosis, and diabetic ketoacidosis.
- Cardiac dysrhythmias occur infrequently unless the hypokalemia is severe (serum $K^+ < 2.3$ mEq/L).
- Electrocardiogram (ECG) findings include low-voltage, flattened T waves, and prolonged QT interval.
- Management
  - Use IV potassium replacement if the child is nauseated and vomiting; continuous replacement is preferred over potassium chloride "bolus" therapy.
    - Potassium chloride infusions should not exceed 1 mEq/kg and should not be delivered faster than over 60 to 90 minutes (maximum 25 mEq KCl).
    - Patient should be observed closely on a cardiac monitor.
    - Peripheral veins will routinely tolerate up to 40 mEq/L KCl in IV fluids.
  - Consider adding potassium chloride supplements to enteral feeds in the absence of vomiting.
    - No oral potassium should be given 1 hour before or after an IV potassium bolus.
    - Administer 1 mEq/kg/dose added to formula or with a meal 3 to 4 times daily, depending on the degree of hypokalemia.
    - Do not exceed 1 mEq/oz of enteral formula during tube feeds.

Hyperkalemia

- Etiologies include excessive potassium administration, acidosis, significant cell destruction, and reduced renal excretion of potassium.
- Common signs include generalized muscle weakness and flaccidity ($K^+ > 6.2$ mEq/L).

- ECG findings include a tall, peaked T wave on ECG initially, followed by widened QRS, ST segment depression, and increasing R wave amplitude.
- As serum potassium level rises, PR interval prolongs, and ventricular fibrillation may occur.
- Management includes frequent assessments and careful monitoring of input and output (ie, fluids in and urine and drainage out).
- Emergent management should be performed rapidly and sequentially.
  - If the patient is not already fluid overloaded, rapidly reexpand intravascular volume with NS 10 to 20 mL/kg.
  - Administer calcium gluconate 100 mg/kg over 5 minutes (maximum dose is 2 g). Give IV calcium through a central line, if available. Calcium preparations can cause skin burns if the peripheral IV is infiltrated; flush with NS before giving bicarbonate.
  - Use sodium bicarbonate (1 mEq/kg over 5 min) in the presence of metabolic acidosis.
  - Glucose and insulin therapy is very effective in children; give 0.5 g/kg of glucose (5 cc/kg of D_{10}) and 0.1 unit/kg of insulin over 30 minutes, simultaneously but in separate drips.
  - Administer sodium polystyrene sulfonate 1 g/kg/dose (maximum dose 30 g, onset of action 1–2 hours) diluted in 3 to 4 mL of water every 6 hours orally, nasogastrically, or rectally.
  - Consider giving an inhaled albuterol treatment, which will begin to lower the serum potassium level in 30 minutes.
  - Consider furosemide 0.5 to 1 mg/kg IV to augment potassium losses in urine.

Hyponatremia

- Common etiologies include hyponatremic dehydration due to excessive sodium loss or diuretic use; syndrome of inappropriate antidiuretic hormone (SIADH), and cerebral salt wasting syndrome. This can be seen with major head trauma or meningitis (Table 25-3).

- Checking urine sodium and osmolality and assessing hydration status will determine the underlying pathophysiology of the disorder.
- Hyponatremic dehydration can be corrected over 24 hours, with half the deficit replaced in the first 8 hours.
- Sodium (Na^+) deficit can be calculated as follows:

Na+ deficit = (140 – serum Na+) × weight (kg) × 0.6

  - Add the deficit sodium and water to the daily maintenance sodium and water to derive the most appropriate fluid (at least ½NS, more likely NS).
  - Serum sodium should not rise more than 0.5 mEq/L/h.
  - Potassium chloride (20 mEq/L) may be added when the patient voids.
- Managing SIADH involves relative fluid and free water restriction; use NS to avoid giving free water.
- Managing cerebral salt wasting involves aggressively replacing ongoing salt and water loss with frequent monitoring of serum sodium levels (every 4 hours) during acute management.
  - Replace sodium deficit with a combination of NS and 3% hypertonic saline, ideally through a central line; maximum infusion rate 2 mL/kg/h (1 mEq/kg/h).
  - If no central line is available, a 1:1 mixture of NS and 3% hypertonic saline can be safely infused peripherally.

Hypernatremia

- Etiologies include hypernatremic/hypertonic dehydration and diabetes insipidus.
- Checking urine concentration, sodium, and osmolality and assessing hydration status will help determine the underlying pathophysiology of the disorder.
- Management of hypernatremic dehydration, like all severe hypertonic states (eg, diabetic ketoacidosis) requires a slower correction, usually over 48 to 72 hours, depending on the duration and severity of the hypernatremia (eg, a 10-day-old breast-fed infant whose serum sodium rose to 165 mEq/dL over many days).

- Calculating the sodium deficit can be complex; if all volume lost is assumed to be 140 mEq/L, the most likely calculation error will be avoided.
  - For severe hypernatremic dehydration ($Na^+ \geq 165$), do not use anything less tonic than NS for at least the first 12 h.
  - Sodium level should not fall more than 0.5 mEq/L/h.

Chapter 26

Respiratory Emergencies

Introduction

Breathing should be effortless, and individuals should exhibit respiratory rates and tidal volumes appropriate for their ages (normally 5 mL/kg in spontaneously ventilating infants and children; Table 26-1). A comprehensive equipment table in Appendix C of this book contains weight-based recommendations for all equipment needed to mechanically ventilate an infant or child.

Table 26-1. Pediatric Respiratory Rates

Age (y)	Respiratory Rate (breaths per min)
< 1	30–60
1–3	24–40
4–5	22–34
6–12	18–30
> 12	12–16

Work of Breathing

- Evidence of increased work of breathing in a child may include the following:
  - tachypnea;
  - retractions (intercostal, subcostal, or suprasternal);
  - use of accessory muscles;
  - head bobbing;
  - open-mouth breathing;
  - nasal flaring; and
  - grunting (an ominous sign!).

- Appropriate tidal volume should be judged by thoughtful analysis during auscultation (ie, does the breath sound normal, small, or excessive?).
  - Stridor is an abnormal breath sound that signifies upper-airway obstruction. It is caused by a foreign body, infection, congenital airway anomalies, upper-airway edema, mass effect on the airway, or vocal cord impairment.
  - Grunting is a short, low-pitched sound during exhalation and is an ominous sign.
    - Grunting requires immediate intervention with supplemental oxygen, bag-mask ventilation, or intubation.
    - It is the child's attempt to keep his or her lungs open and sustain oxygenation by maintaining positive end-expiratory pressure.
    - Grunting may be present in a variety of conditions, including pneumonia, pulmonary contusion, and acute respiratory distress syndrome.
  - Wheezing is typically a musical expiratory sound associated with lower-airway obstructive disorders.
    - Asthma and bronchiolitis typically manifest with diffuse polyphonic wheezing, signifying the closure of many airways at different times. Treatment differs for asthma and bronchiolitis (see below).
    - Central airway collapse disorders, such as tracheomalacia or bronchomalacia, typically manifest with monophonic wheezing (the same noise can be heard throughout the chest).
    - In younger children (9–36 months), unilateral wheezing appreciated on examination may indicate partial airway obstruction or retained foreign body.
  - Crackles/rales are inspiratory sounds typically associated with airway or alveolar disease and collapse (pneumonia, atelectasis, pulmonary edema).
  - Pulse oximetry
    - 94% SaO_2 and above is normal for a child.
    - Must be checked on warm, well-perfused extremity.
    - Less than 90% SaO_2 despite 100% oxygen administration may predict impending respiratory failure.

    - Less than 90% SaO_2 requires consideration of previously undiagnosed congenital cyanotic heart disease in infants and children who present with minimal respiratory distress and cyanosis that does not improve despite oxygen.

Status Asthmaticus

- Status asthmaticus is characterized by respiratory distress due to airway obstruction from bronchospasm, excess mucous production, and airway inflammation.
- The following plan can be used for all acutely symptomatic asthma exacerbations (Tables 26-2–26-4):
    - Rapidly categorize severity based on presenting signs and symptoms.
    - Use time-based management (see Tables 26-3–26-5), depending on severity.
    - Evaluate disposition based on response to prompt therapy.
- Admit the patient for management if he or she cannot take medications or fluids orally, cannot maintain saturation at or above 91% SaO_2 on room air, requires bronchodilators more often than every 3 to 4 hours, or if the patient is rapidly deteriorating (see Table 26-5).
- Watch for toxicities and side effects of medications (Table 26-6).
    - For example, extreme tachycardia can be seen when albuterol, ipratropium inhalation, and terbutaline are used in combination.
    - An infant or toddler will tolerate a heart rate of 180 beats per minute, but an adolescent will not.

Managing Chronic Asthma

- Optimal long-term management of asthma leads to fewer acute exacerbations, minimal use of medications (short-acting β-agonists and oral corticosteroids), fewer restrictions on activity, and preservation of lung function. The following steps provide a framework for long-term asthma management:
    - Classify asthma severity.
        - Although spirometry provides an objective means for evaluating lung function, it is unlikely to be available.

Table 26-2. Acute Asthma Severity

	Category			
Signs and Symptoms	**Mild**	**Moderate**	**Severe**	**Imminent Respiratory Failure**
Respiratory rate	30% above mean	30%–50% above mean	> 50% above mean	> 50% above mean, or very slow
Alertness	Normal	Usually agitated	Agitated	Drowsy, confused
Dyspnea	Mild	Moderate	Severe	Severe
Color	Good	Pale	May be cyanotic	Cyanotic
Accessory muscle use	Mild	Moderate	Severe	Paradoxical thoracoabdominal movements
Auscultation	End-expiratory wheeze	Inspiratory and expiratory wheezing	Inaudible wheezing	Inaudible wheezing, minimal breath sounds
PEFR (% of predicted)	70%–90%	50%–70%	< 50%	< 20%
Air movement	Good	Fair	Poor	Poor/absent
$PaCO_2$	< 35 mmHg	< 40 mmHg	> 40 mmHg	> 40 mmHg

PEFR: peak expiratory flow rate
$PaCO_2$: partial pressure of carbon dioxide in arterial blood
Adapted from: National Institutes of Health, National Heart, Lung, and Blood Institute. *Guidelines for the Diagnosis and Management of Asthma*. Bethesda, MD: NIH; 1991.

Table 26-3. Acute Asthma Treatment for Mild to Moderate Attacks

Timeframe	Treatment
Presentation	Check vitals and pulse oximetry; take brief history and perform PE, administer supplemental oxygen for sat ≤ 90%, preferably keeping sat ≥ 94%
10–20 min	Administer an immediate β-agonist (eg, albuterol): MDI with spacer 4–8 puffs **OR** Albuterol (nebulized) 2.5–5 mg Reassess and repeat q10–20min; consider adding ipratropium to subsequent nebulizer 0.25–0.5 mg
30 min	Consider steroids: Oral prednisone 1 mg/kg **OR** Methylprednisolone sodium succinate (IV or IM) 1 mg/kg if unable to tolerate PO, max dose 60 mg
60 min	Consider MgSO4: 50 mg/kg over 20 min and reassess (maximum single dose 2 g)
120–240 min	Patient may be discharged if clinically improved with sat ≥ 94% and reliable follow-up established

IM: intramuscular
IV: intravenous
MDI: metered-dose inhaler
MgSO4: magnesium sulfate
PE: physical examination
PO: per os (by mouth)
sat: saturation
SQ: subcutaneous

- Classifying asthma severity using an age-based table can help guide initial management (Table 26-7).

- Control precipitating factors and comorbid conditions.
  - Identification and avoidance of known triggers, along with aggressive use of rescue medications, can help minimize symptoms.

Table 26-4. Acute Asthma Treatment for Severe Attacks

Timeframe	Treatment
Presentation	Check vitals and pulse oximetry; take brief history and perform PE, administer supplemental oxygen for sat ≤ 90%, preferably keeping sats ≥ 94%
10–20 min	Administer an immediate β-agonist: Albuterol (nebulized) 2.5–5 mg. Reassess and repeat q10–20min **OR** Terbutaline or epinephrine (1:1,000) 0.01 mg/kg (SQ) if unresponsive to albuterol or not moving air; may repeat in 15 min; max dose 0.3 mg Add ipratropium to subsequent nebulizer 0.25–0.5 mg
30 min	Steroids: Methylprednisolone sodium succinate 1–2 mg/kg IV and reassess
60 min	$MgSO_4$ 50 mg/kg over 20 min and reassess (max single dose 2 g) Continue nebulizer as necessary
120–240 min	Admit or transfer for ICU care if not improved

IV: intravenous
MgSO4: magnesium sulfate
PE: physical examination
PICU: pediatric intensive care unit
sat: saturation
SQ: subcutaneous

- Common triggers include upper respiratory infections, inhaled allergens (eg, pollen, dust mites), and irritants (eg, tobacco smoke, perfumes).
- Comorbid conditions, such as rhinitis, reflux, obesity, and stress, are known to worsen asthma symptoms and should be treated.

- Provide asthma education.
  - Education should focus on the appropriate use of medications (proper use of inhaler, chamber, and spacer), avoiding environmental exposures, recognizing worsening symptoms and adjusting medications, and seeking appropriate medical care when needed.

Table 26-5. Asthma Inpatient Management Plan

Ward	Pediatric Intensive Care Unit
If O_2 sat ≥ 94% on ≤ 50% FiO_2 requires ≤ q2–3h albuterol PRN (MDI with spacer or nebulized)	If patient remains in distress, use albuterol continuously (0.6 mg/kg/h, range 10–40 mg/h) with O_2 to keep O_2 sat ≥ 94% (always use humidified O_2)
Use prednisone 2 mg/kg/day or methylprednisolone sodium succinate 2–4 mg/kg/day ÷ q6h	Use terbutaline drip as adjunct, bolus with 10 μg/kg over 10 min, then run drip .1 μg/kg/min, titrating q15–30 min, up to max of 4 μg/kg/min
Consider ipratropium neb 0.25–0.5 mg q4–6h	Use methylprednisolone sodium succinate 4 mg/kg/day ÷ q6h
Consider $MgSO_4$ 50 mg/kg IV q6h (if not already given)	Ipratropium neb 0.25–0.5 mg q4-6h
Consider temporary NPO status with maintenance IVFs if in distress	Consider repeating $MgSO_4$ 25–50 mg/kg IV q6h
Discharge patient to home if clinically improved with O_2 sat ≥ 94%, and reliable follow-up established	Consider temporary NPO status with maintenance IVFs if in distress, especially if intubation is possible
	Other options include: Heliox 70:30
	Ketamine sedation 0.5–1 mg/kg/dose for agitation out of proportion to respiratory distress. CAUTION: may cause respiratory depression
	Inhaled anesthetics

FiO_2: fraction of inspired oxygen
IV: intravenous
IVF: intravenous fluid
MDI: metered dose inhaler
$MgSO_4$: magnesium sulfate
neb: nebulized
NPO: nil per os (nothing by mouth)
PRN: pro re nata (as needed)
sat: saturation

Table 26-6. Asthma Medication Toxicity Profile

Medication	Toxicity
Albuterol	Tachycardia, hypokalemia, tremors
Ipratropium	Dry mouth, tachycardia, dry secretions
Terbutaline	Tachycardia, arrhythmias, hypokalemia, muscle twitching, increased muscle CPK, headache, seizure
Steroids	Hyperglycemia, gastritis, CNS stimulation, hypertension, immune suppression
Magnesium	Hypotension, weakness, nausea, flushing, diarrhea
Ketamine	Potent sialogogue, respiratory depression, emergence phenomena, tachyphylaxis
Inhaled anesthetics	Hypotension, apnea, myocardial depression

CNS: central nervous system
CPK: creatine phosphokinase

- A written asthma action plan is a validated educational tool.

Other Common Respiratory Emergencies

- Anaphylaxis
  - Several organ systems may be involved, including the skin, respiratory tract, cardiovascular system, and gastrointestinal tract.
  - If not recognized and promptly treated, anaphylaxis may lead to death from respiratory or cardiovascular collapse.
  - Causes can include foods, drugs, and hymenoptera venom.
    - Foods: peanuts, tree nuts, milk, eggs, fish, shellfish, fruits, grains.
    - Drugs: penicillins, cephalosporins, sulfonamides, nonsteroidal antiinflammatory drugs, opiates, insulin, local anesthetics.
    - Hymenoptera venom: honeybee, yellow jacket, wasp, hornet, and fire ant venom.
    - Other: latex, exercise, vaccinations.

Table 26-7. Chronic Asthma Severity and Suggested Treatment

Severity	Intermittent	Mild	Moderate	Severe
Frequency of symptoms	< 2/wk	> 2/wk (not daily)	Daily	Throughout day
Nighttime awakenings	None	1–2/mo	3–4/mo	> 1/wk
Impairment	None	Minor	Moderate	Extremely limited
Treatment	Albuterol PRN	Low-dose ICS or LTRA and albuterol PRN	Low- or medium-dose ICS + LABA or LTRA and albuterol PRN	Medium- or high-dose ICS + LABA or LRTA and albuterol PRN Consider systemic cortico-steroids

ICS: inhaled corticosteroid
LABA: long-acting beta-adrenoceptor agonist
LTRA: leukotriene receptor antagonist
PRN: pro re nata (as needed)

- Evaluation should proceed as follows:
  - History should include investigations into interaction with anaphylaxis-associated allergens via contact, ingestion, inhalation, or medication administration; inquiries into previous history of anaphylaxis; and past medical history.
  - Review of symptoms and physical examination should check for the following:
    - Dermatologic: urticaria, angioedema, pruritus, flushing, or warmth.
    - Oropharynx: swelling of the lips, tongue, or mouth.
    - Throat: hoarseness, cough.
    - Pulmonary: dyspnea, wheeze.
    - Gastrointestinal: nausea, vomiting, diarrhea, or

abdominal pain.
        - Cardiovascular: hypotension, dizziness, syncope, or cardiovascular collapse.
    - Treatment is as follows:
        - Immediate
            - Check airway, breathing, and circulation.
            - Administer epinephrine 0.01 mg/kg (1:1,000) intramuscular (IM):
            - Maximum single dose: 0.3 mg.
            - Repeat every 15 minutes as needed.
            - Auto injectors: epinephrine 0.15 mg (10–25 kg) or epinephrine 0.3 mg (> 25 kg).
            - Obtain intravenous (IV) access, administer 100% oxygen, observe cardiac monitor and pulse oximetry.
            - Bolus normal saline (NS) 20 cc/kg, repeat as needed for hypotension.
        - Therapy after epinephrine
            - H1 antagonist (diphenhydramine 1–2 mg/kg PO/IM/IV), maximum single dose 50 mg.
            - Corticosteroids (prednisone 1–2 mg/kg PO or methylprednisolone 2 mg/kg IV).
            - Consider nebulized albuterol 1.25 to 2.5 mg every 20 minutes for bronchospasm.
            - Consider an H2 antagonist (ranitidine 2 mg/kg PO or IV).
    - Disposition
        - Following initial stabilization, observe patient at least 4 hours (may have biphasic response).
        - Discharge patient with 72 hours of antihistamine and corticosteroids (albuterol if bronchospasm is present).
        - Prescribe an epinephrine auto injector (use age-based dosing).
        - Educate patient on anaphylaxis trigger avoidance and proper use of epinephrine auto injector.
- Bronchiolitis
    - Bronchiolitis is an acute, infectious, inflammatory disease of the upper and lower respiratory tracts leading to coughing, wheezing, and respiratory distress. Most cases are mild and self-limiting; however, inpatient mortality can be

significant.

- Causes: bronchiolitis is most often caused by respiratory syncytial virus, but other viruses and mycoplasma have been implicated. Premature, chronically ill, or malnourished infants are at higher risk for severe disease.
- Evaluation
  - Bronchiolitis may present with a low-grade fever and nasal congestion that can progress to lower tract symptoms with cough, dyspnea, wheezing, and feeding difficulties.
  - Severe cases can manifest with respiratory distress, tachypnea, nasal flaring, retractions, irritability, and cyanosis.
  - Biphasic wheezing and crackles during auscultation are common.
  - Hypoxemia on pulse oximetry is the best predictor of severe illness and correlates with a respiratory rate greater than 50 breaths per minute.
  - Patients can present with otitis media, myocarditis, dysrhythmias, and syndrome of inappropriate antidiuretic hormone.
  - A significant number of young or premature infants will have apnea.
  - Chest radiograph, although not necessary, will show hyperexpansion and diffuse bilateral perihilar peribronchial cuffing.
- Treatment
  - Admit patient for respiratory distress, room air saturation values less than 92% SaO_2, dehydration, apnea, or hypothermia.
  - Therapy is supportive, using oxygen and IV fluids in infants who are hypoxemic and cannot take oral liquids.
  - Excess fluid administration may exacerbate pulmonary edema.
  - Some infants may experience short-term symptom relief with nebulized albuterol or racemic saline.
  - Mild nasal decongestants or bulb suctioning are more likely to be of symptomatic benefit than nebulized

albuterol or reacemic saline.
- ▸ Antibiotics are not indicated unless there is a strong suspicion of a secondary bacterial process.
- ▸ If mechanical ventilation becomes necessary, use synchronized intermittent mechanical ventilation with pressure support and positive end-expiratory pressure, ventilating at relatively slow rates to allow adequate exhalation time.

- Croup
  - ◦ Laryngotracheobronchitis is an infection of the upper airway characterized by inspiratory stridor, cough, wheezing, and hoarseness.
  - ◦ Causes include the following:
    - ▸ The etiology is predominately viral infection (parainfluenza, respiratory syncytial virus, adenovirus).
    - ▸ Often occurs during winter or cooler months.
    - ▸ Measles can be a cause in unimmunized populations.
  - ◦ Evaluation
    - ▸ Children ages 3 to 36 months typically present with gradually developing symptoms, including a barky cough, hoarse voice, inspiratory stridor, tachypnea, and retractions (usually worse at night).
    - ▸ Significant hypoxia, biphasic stridor, change in mental status, poor air movement, or apparent fatigue may suggest impending respiratory failure and require urgent management.
    - ▸ Chest radiograph will demonstrate laryngeal narrowing or "steeple sign."
  - ◦ Treatment
    - ▸ Urgent treatment includes rapid-acting nebulized racemic epinephrine (0.25–0.5 mL) of 2.25% solution diluted to 3.0 cc with NS, repeated as needed.
      - ▹ Rapid onset, short duration (about 2 h).
      - ▹ Patients should be monitored closely for rebound symptoms 2 hours after nebulized treatment; tachyphylaxis may occur with repeated dosing.
      - ▹ If racemic epinephrine is unavailable, use L-epinephrine (0.5 mg/kg, maximum dose 5 mL of

1:1,000 solution).

- Corticosteroids are the mainstay of treatment to decrease airway edema.
  - Onset of action is around 6 hours.
  - Dexamethasone: 0.6 mg/kg IV/IM/PO (IV formulations can be given orally once, max dose 16 mg),

OR

  - Prednisolone: 2 mg/kg/day IV divided bid for 2 to 3 days,

OR

  - Prednisone: 4 mg/kg PO (equivalent to 0.6 mg/kg dexamethasone).
- Management includes supplemental oxygen and supportive measures, including IV fluids and humidified air.

- Epiglottitis (see also Chapter 16, Face and Neck)
  - Epiglottitis is a rapidly progressive bacterial infection of the epiglottis, aryepiglottic folds, and surrounding tissues that leads to edema, airway compromise, and respiratory failure.
  - Causes
    - More common in unimmunized populations due to *Haemophilus influenzae* type b.
    - Rare causes in immunized populations include: *Pneumococcus*, *Staphylococcus aureus*, group A β-hemolytic streptococci (GABHS), and nontypeable H influenzae.
  - Evaluation
    - Children ages 1 to 5 years old can present with a rapid progression from minimal symptoms to fever, sore throat/dysphagia, inability to manage secretions, and toxic appearance.
    - Airway compromise appears rapidly with respiratory distress; patient may exhibit a muffled "hot-potato" voice (sounds like a person speaking with a hot potato in his or her mouth) and abnormal positioning (tripoding or leaning forward with mouth open) to maintain maximum airway patency.
    - Hoarseness and stridor are typically absent or mild.

- Work of breathing is normal to minimally elevated.
- Clinical diagnosis is based on high index of suspicion; cherry-red epiglottis may be seen on passive visualization without instrumentation.
- Aggressive attempts to visualize the airway should be avoided until skilled personnel are present (ie, an anesthesia professional and a surgeon capable of performing emergent pediatric tracheostomy) and prepared to intervene.
- Lateral neck radiographs should be obtained with caution in children with airway concerns; however, the enlarged epiglottis can be visualized (it appears as the so-called "thumb sign" on the lateral neck).

◦ Treatment

- Total airway obstruction may occur due to the massively enlarged epiglottis.
- Management includes intubation, by the most experienced provider, with an endotracheal tube 0.5 to 1.0 size smaller than that routinely used for a child of that age and size.
- Simple bag-valve mask ventilation may be successful if absolutely necessary.
- Once the child is intubated, it is critical to secure the endotracheal tube and sedate the child sufficiently to avoid a potentially catastrophic self-extubation.
- Treatment includes broad-spectrum IV antibiotics (do not exceed maximum adult dose).
- Oxacillin/nafcillin (150–200 mg/kg/day divided four times daily),

OR

- Cefazolin (75–100 mg/kg/day divided three times daily),

OR

- Clindamycin (30–40 mg/kg/day divided three times daily),

PLUS

- Third-generation cephalosporin (ceftriaxone 75–100 mg/kg/day divided twice daily).

        - Cover for methicillin-resistant *S aureus* in endemic area.
- Bacterial Tracheitis
    - Symptoms: similar to croup but with high fever, toxic appearance, and progressive airway obstruction.
        - Tendency to have insidious onset, which may differentiate this illness from epiglottitis.
        - Copious purulent secretions arise from the trachea; the child may expectorate these and the secretions will make frequent suctioning necessary.
    - Etiology: usually *S aureus*, also GABHS, *Haemophilus influenzae* type b, or *S pneumonia*.
    - Diagnosis: clinical; trachea may appear "shaggy" on radiograph.
    - Treatment
        - Intubate and ventilate patient for 5 to 7 days (usually needed for pulmonary toilet).
        - May require flexible or rigid endoscopy for secretion removal.
        - Administer nafcillin, cefazolin, cefuroxime, or ampicillin/sulbactam, all IV.
        - Cover for methicillin-resistant *S aureus* in endemic areas.

Chapter 27

Cardiology

History

- In newborns, exercise tolerance is approximated by asking caregivers about feeding difficulties, specifically tachypnea, cyanosis, and diaphoresis during feeding.
- In infants, failure to thrive (gain weight at an appropriate rate) warrants consideration of congenital heart disease.
- Children with other congenital anomalies are more likely to have congenital heart disease, particularly defects along the midline or involving other solid organs. Family history should focus on family members with heart disease (congenital or acquired), sudden unexplained deaths, and arrhythmias.

Examination

- Blood pressure should be measured in both of the patient's arms and one leg to evaluate for coarctation of the aorta (in normal patients without coarctation, blood pressure should be slightly higher in the leg).
- Murmurs are noted in more than 90% of all children at some time in their lives. Most murmurs are harmless. Characteristics concerning for a pathologic murmur include associated cardiac symptoms, a loud or harsh-sounding systolic murmur (> 3/6 or with a palpable thrill), a diastolic murmur, abnormal heart sounds, presence of a click, and weak or absent peripheral pulses.
- Electrocardiograms (ECGs) are helpful if they are available (consult *The Harriet Lane Handbook* for help interpreting an ECG).

Evaluating the Cyanotic Newborn, Infant, and Child

- Central cyanosis is universally consistent with hypoxemia and is best appreciated in the oral mucosa, conjunctivae, and the tip of the tongue.
- The most common cause of cyanosis in newborns, infants, and children is respiratory compromise from a host of pulmonary diseases.
- Cyanosis from congenital heart disease is typically due to a right-to-left intracardiac shunt and persists beyond the newborn period.
- Evaluation
  - Initial evaluation should include pulse oximetry and measurement of the partial pressure of oxygen in arterial blood (PaO_2) by blood gas to confirm hypoxemia. The PaO_2 in a normal, 1-day-old newborn may be as low as 60 mmHg.
  - Primary pulmonary processes are associated with tachypnea, increased work of breathing, and dyspnea; congenital cyanotic heart defects are generally associated with effortless tachypnea (often described as "comfortable tachypnea").
    - If a cyanotic heart defect is suspected, perform chest radiograph, ECG (if available), and a hyperoxitest.
    - Ultimately, the diagnosis of congenital cyanotic heart disease is made by echocardiography.
    - The hyperoxitest compares PaO_2 and pulse oximetry values after a 100% oxygen challenge as a means of differentiating pulmonary from cardiac causes of hypoxemia.
      - Arterial blood gas samples should be taken from the right upper extremity.
      - PaO_2 and pulse oximetry values are taken while the newborn is breathing fraction of inspired oxygen (FiO_2) of 0.21, and after FiO_2 is increased to 1.00 for 10 minutes.
      - Care should be taken to get the FiO_2 as close as possible to 1.00.
      - Pulmonary disease: PaO_2 greater than 150 mmHg and pulse oximetry equal to 100% arterial oxygen saturation, with FiO_2 equal to 1.00.

        - Cardiac disease: PaO_2 less than 150 mmHg and pulse oximetry less than 90% Arterial Oxygen Saturation, with FiO_2 equal to 1.00.
- Treatment
    - Although some children with cyanotic heart defects can survive past infancy (eg, most commonly those with mild forms of tetralogy of Fallot), definitive treatment of cyanotic heart defects requires surgical correction.
    - In the newborn period, if surgical intervention is a feasible option, a prostaglandin E1 (PGE1) intravenous (IV) infusion can be started to maintain patency of the ductus arteriosus; however, this medication is unlikely to be on standard Role 3 formularies.
        - Currently, there are no alternative drugs to PGE1.
        - The starting dose of PGE1 is 0.05 to 0.1 μg/kg/min and may be titrated up to 0.4 μg/kg/min.
        - Clinical evidence of the ductus reopening, typically within 1 to 2 hours, will include improved pulse oximetry, perfusion, blood pressure, and urine output, as well as improved arterial pH and partial pressure of oxygen. Once the ductus is reopened the dose can be reduced and the infusion continued until balloon atrial septostomy or cardiac surgery is performed.
        - Common side effects include flushing, apnea, hypotension, fever, and seizure-like activity; be prepared to intubate when starting PGE1.

Arrhythmias

- See Pediatric Advanced Life Support resuscitation algorithms on the card located inside the front cover of this book.

Bradycardia

- The most common cause of true bradycardia in infants and children is hypoxia, usually due to respiratory compromise.
- Sinus bradycardia can be normal in adolescents and athletes.
- Bradycardia can also be caused by increased vagal tone, increased intracranial pressure, hyperkalemia, hypercalcemia, hypothyroidism, hypothermia, long QT syndrome, and drugs (eg, digoxin, β-blockers, calcium channel blockers, lithium).

- In newborns, physiological stresses (eg, hypoxia, cold, hypoglycemia) are often manifest as bradycardia (but manifest as tachycardia in older children and adults).
- Bradycardia can also occur as a result of heart block.
- Management
  - Treat the underlying cause.
  - A hemodynamically unstable patient with underlying bradycardia requires emergent attention.
  - Begin with effective oxygenation and ventilation via bag-valve mask, if necessary.
  - Epinephrine IV or intraosseous is the drug of choice after oxygen; dose 0.01 mg/kg (0.1 mL/kg) of 1:10,000 repeat every 3 to 5 min.
  - Atropine should be considered a second-line agent, unless vagal stimulation is thought to be the source of the bradycardia. Dose 0.02 mg/kg (minimum dose 0.1 mg, max 1 mg); may be repeated once.

Tachycardia

- The most common cause of tachycardia in pediatric patients is sinus tachycardia, which can be caused by hypovolemia, hemorrhage, hypoxia, anemia, fever, sepsis, shock, congestive heart failure, myocardial disease, anxiety, and drugs (eg, β-agonists, atropine).
- Management requires distinguishing sinus tachycardia from supraventricular tachycardia (typically narrow QRS complex) and ventricular tachycardias (wide QRS complex).
  - Sinus tachycardia is almost always accompanied by a history that explains it (volume loss, fever, hemorrhage, etc).
  - Maximum heart rates for infants and children can be surprising:
    - Infants: up to 220 beats per minute (bpm).
    - Children: 210 bpm.
    - Adolescents: 200 bpm.
- Treatment involves correcting the underlying causes.
- Supraventricular tachycardia is the most common tachyarrhythmia seen in children, with increased ventricular rates (often > 220 bpm).
  - P waves, if visible, are usually abnormal.

- This typically manifests as a paroxysmal start/stop, rather than a warm-up and cool-down.
- Heart rate is regular, rapid, and monotonous, with minimal variation.
- Narrow QRS complexes are typical.
- Supraventricular tachycardia can be associated with congenital heart disease (eg, Ebstein's anomaly, transposition) and preexcitation syndromes, like Wolff-Parkinson-White syndrome.
- It is most often idiopathic.
- Treatment includes vagal maneuvers (ice to the face, blowing through a straw, or Valsalva) and adenosine (initially 0.1 mg/kg/dose) IV administered quickly, followed immediately by a flush of 5 to 10 cc normal saline; given its short half-life, adenosine may be repeated at 0.2 mg/kg if necessary.
- If the patient is unstable, perform synchronized cardioversion (0.5–1 J/kg).

Atrial Flutter

- Atrial flutter is very rare in children without structural heart disease and is usually associated with a narrow complex tachycardia (unlike in adults) secondary to excellent conduction through the atrioventricular node.
- Acute treatment of unstable patients requires synchronized cardioversion or overdrive pacing; medical therapy including anticoagulation, digoxin, procainamide, and short-acting β-blockers may be started in consultation with a pediatric cardiologist.

Atrial Fibrillation

- Atrial fibrillation is very rare in children and may be hereditary or associated with structural heart disease.
- It is defined as an irregular-appearing and fast atrial rate (350–600 bpm), narrow QRS complexes, and an irregular ventricular response rate of 110 to 150 bpm.
- Anticoagulation may be necessary if atrial fibrillation is present for more than 48 hours.

- Acute treatment of unstable patients requires synchronized cardioversion; medical therapy including anticoagulation, calcium channel blockers, and β-blockers may be started in consultation with a pediatric cardiologist.

Ventricular Dysrhythmias

- Premature ventricular contraction (PVC)
  - PVC is typically benign; multifocal PVCs are more concerning.
  - Causes of PVCs include myocarditis, cardiomyopathy, congenital and acquired heart disease, long QT syndrome, hypokalemia, hypoxemia, hypomagnesemia, anxiety, and drugs (eg, digitalis, catecholamines, caffeine, and anesthetics).
  - Treatment is only necessary if the PVCs are associated with symptoms, hemodynamic changes, underlying heart disease, high frequency (> 25% of total beats), or are made worse with exercise.
  - Treatment can include β-blockers and other antiarrhythmic drugs or catheter ablation.
- Ventricular tachycardia (VT) and ventricular fibrillation (VF)
  - VT and VF represent the initial arrest rhythm in only 10% of pediatric cardiopulmonary arrests, but will appear in up to 25% of resuscitations (see Samson, et al, in Further Reading).
  - For stable VT, consider a slow load of amiodarone 5 mg/kg IV, but be prepared to cardiovert or defibrillate if necessary.
  - For pulseless VT and VF, treat with immediate cardiopulmonary resuscitation, defibrillate 2 to 4 J/kg, and administer IV epinephrine 0.01 mg/kg then either lidocaine (1 mg/kg) IV or amiodarone (5 mg/kg) IV bolus.

Congestive Heart Failure

- Congestive heart failure (CHF) can be caused by a variety of congenital or acquired medical conditions.
- By far, the most common cause of CHF in infancy is congenital heart disease.

- Volume overload lesions (left to right anatomic shunts), such as ventricular septal defect, patent ductus arteriosus, and endocardial cushion defects are most common.
- Tachyarrhythmias and heart block can cause heart failure at any age, including in utero.
- Acquired heart diseases become more common as children get older. These conditions include myocarditis, acute rheumatic carditis, rheumatic valvular diseases with significant mitral or aortic regurgitation, dilated cardiomyopathy, metabolic abnormalities, endocrinopathies, and severe anemia.

- Diagnosis
  - Infants present with tachycardia, hepatosplenomegaly, poor feeding, tachypnea that worsens during feeding, poor weight gain, and diaphoresis, particularly with feeding.
  - Older children may report dyspnea (particularly with activity), orthopnea, easy fatigability, abdominal discomfort, and swelling of the eyelids, feet, and hands.
  - Like in adults, the following are common physical exam findings consistent with but not specific to CHF:
    - wheezes or crackles,
    - tachycardia,
    - gallop rhythm,
    - displaced point of maximal impulse,
    - weak pulses,
    - hepatosplenomegaly, and
    - extremity and eyelid edema.
  - Unlike in adults, jugular venous distention is not a common finding.
  - Cardiomegaly is almost always seen on a chest radiograph.
- Management
  - Address the underlying etiology, provide support, and control underlying heart failure state.
  - Supportive measures include providing adequate calories given fluid restrictions (for infants with volume overload lesions, this may be > 140–150 kcal/kg/day, often given via nasogastric tube; see Schwarz, et al, in Further Reading).
  - Medical management includes a combination of inotropic agents, diuretics, and afterload-reducing agents.

Acquired Heart Disease

Rheumatic Heart Disease

- Acute rheumatic fever is a common cause of heart disease in underdeveloped countries.
- Pathophysiology includes a postinflammatory reaction affecting the whole body.
  - Rheumatic heart disease is believed to be immunologically mediated following a group A streptococcal infection of the pharynx.
  - Other streptococcal infections, like impetigo, do not typically cause acute rheumatic fever.
  - Most cases occur in children between 6 and 15 years old (peak incidence at 8 years old), 1 to 5 weeks after streptococcal pharyngitis, with nonspecific symptoms of malaise, fatigue, abdominal pain, and pallor; there may be a positive family history of rheumatic fever.
  - The diagnosis is ultimately made using the revised Jones Criteria (Exhibit 27-1) and requires two major manifestations or one major and two minor manifestations, in addition to evidence of an antecedent streptococcal pharyngitis by either throat culture or serology.

Exhibit 27-1. Diagnostic Criteria for Rheumatic Fever: Jones Criteria

Major Criteria	Minor Criteria
Carditis	Fever
Chorea	Arthralgia
Polyarthritis	Elevated ESR or CRP
Erythema marginatum	Prolonged PR interval (ECG)
Subcutaneous nodules	

CRP: C-reactive protein
ECG: electrocardiograms
ESR: erythrocyte sedimentation rate

- While rheumatic fever is systemic inflammatory disease, the major long-term consequences are due to rheumatic heart disease caused by a pancarditis.
  - Pancarditis involves the pericardium, myocardium, endocardium, and epicardium.
  - Valvulitis is commonly present.
- In the acute phase, mitral regurgitation (regurgitant systolic murmur) with or without aortic insufficiency (diastolic murmur) is the most common cardiac manifestation.
- Carditis should also be suspected in the presence of new onset CHF or pericardial friction rub in a patient with a murmur and suspicious clinical history.
- Clinical examination is the basis of diagnosing rheumatic fever and carditis, but echocardiography, if available, would be supportive. See Chapter 29, Infectious Diseases, for treatment regimens.

Kawasaki disease

- Kawasaki disease is an acute, febrile vasculitis of unknown etiology, with a predilection for the coronary arteries.
- It is the most common cause of acquired heart disease in developed countries and seen almost exclusively in children less than 8 years old.
- Diagnosis is clinical and based on a history of high fever lasting 5 days or more, plus four of the following five criteria:
  - bilateral bulbar conjunctivitis without exudates;
  - erythema of the mouth and pharynx, strawberry tongue, or red and cracked lips;
  - nonspecific polymorphous exanthema;
  - swelling of the hands and feet, with erythema of the palms and soles; and
  - cervical lymphadenopathy (> 1.5 cm), usually single or unilateral.
- Additional associated features include extreme irritability, abdominal pain, vomiting, diarrhea, and skin changes (particularly desquamation of the hands, feet, and perineal region), usually after the fever ends.

- Laboratory findings include elevated erythrocyte sedimentation rate (ESR) and C-reactive protein, leukocytosis with left shift, normocytic anemia, thrombocytosis, sterile pyuria, and elevated liver enzymes.
- If left untreated, there is a 15% to 25% risk of coronary artery aneurysm and subsequent coronary artery thrombosis and stenosis, although aneurysms can develop elsewhere in the body.
  - Rarer complications include carditis, valve regurgitation, pericardial effusion, and CHF.
  - Treatment
    - Administer one dose of IV immunoglobulin (2 g/kg over 12 h).
    - Give high-dose aspirin (80–100 mg/kg/day divided into four doses) per os (PO) until the fever resolves, followed by 3 to 5 mg/kg/day of aspirin PO once a day for 6 to 8 weeks when an echocardiogram demonstrates normal coronary arteries and the ESR and platelet count have returned to normal.

Infective Endocarditis Prophylaxis

- The use of antibiotic prophylaxis to prevent bacterial endocarditis was greatly changed in 2007. Under current guidelines, prophylaxis is recommended for only the following procedures:
  - Dental procedures that involve manipulation of gingival tissues, the periapical region of teeth, or perforation of oral mucosa.
  - Procedures on the respiratory tract involving incision of the respiratory tract mucosa.
  - Procedures on infected skin, skin structures, or musculoskeletal tissue.
- Prophylaxis is no longer recommended for procedures involving the gastrointestinal or genitourinary tracts.
- Cardiac conditions for which endocarditis antibiotic prophylaxis is indicated include:
  - prosthetic cardiac valve;
  - unrepaired cyanotic heart disease;
  - congenital heart defects completely repaired with a

prosthetic material or device (placed surgically or by catheter) during the first 6 months after the procedure;
    - repaired congenital heart defects with residual defects at the site or adjacent to the site of a prosthetic patch or prosthetic device;
    - cardiac transplantation recipients with cardiac valvulopathy; and
    - previous infective endocarditis.
- Medication and dosing administered as a single dose 30 to 60 min before the procedure:
    - Amoxicillin: 50 mg/kg PO to a max dose of 2 g.
    - Ampicillin: 50 mg/kg IV to a max dose of 2 g.
    - Azithromycin: 15 mg/kg to a max dose of 500 mg.
    - Clindamycin: 20 mg/kg PO or IV to a max dose of 600 mg.
    - Cephalexin: 50 mg/kg to a max dose of 2 g.
    - Ceftriaxone 50 mg/kg to a max dose of 1 g.
    - Vancomycin: 15 mg/kg to a max dose of 1 g.

Cardiac Syncope

- Although syncope is usually the result of vasovagal and orthostatic mechanisms, cardiac causes of syncope include:
    - Obstructive heart lesions, such as:
        - aortic stenosis,
        - severe pulmonary stenosis, and
        - hypertrophic cardiomyopathy.
    - Coronary artery abnormalities.
    - Arrhythmias.
- Red flags during the evaluation of syncope include:
    - exercise-induced syncope;
    - preceding chest pain;
    - associated seizure-like activity;
    - absence of prodromal symptoms, such as tunnel vision, seeing spots, and muffled hearing;
    - physical examination suggestive of cardiac disease;
    - abnormal ECG; and
    - unexplained death or aborted sudden death in a family member under age 40.

Chest Pain and Myocardial Infarction

- Chest pain is a frequent chief complaint among children and adolescents, but it is rarely due to any underlying cardiovascular cause. The most common etiologies of chest pain among pediatric patients are:
  - Musculoskeletal pain from muscle strain, chest wall deformities like pectus excavatum, costochondritis, or precordial catch syndrome (localized chest wall pain at rest lasting seconds to minutes and made worse with deep inspiration).
  - Respiratory conditions, such as:
    - pneumonia,
    - cough and asthma.
  - Gastrointestinal disease, specifically esophagitis related to gastroesophageal reflux disease.
  - Psychogenic etiologies, including anxiety.
- Red flags for underlying cardiovascular disease include:
  - exertional chest pain not consistent with asthma symptoms;
  - pain that radiates down the left arm or up the neck, jaw, or into the back;
  - associated presyncope or syncope;
  - palpitations; and
  - dull, squeezing, or heavy chest pain (as opposed to sharp or pinpoint pain that is often reproducible, worse with taking a deep breath, and worse on palpation).
- Cardiac causes of chest pain include:
  - obstructive congenital heart conditions that put additional strain on the myocardium, such as aortic stenosis, subaortic stenosis, coarctation of the aorta, and pulmonary stenosis;
  - cardiomyopathy;
  - coronary artery abnormalities;
  - aortic dissection or aneurysm;
  - pericarditis;
  - myocarditis; and
  - arrhythmias.

Myocardial Infarction

- Myocardial infarction is rare in children.
- Predisposing conditions include history of Kawasaki disease, anomalous origin of a left coronary artery, congenital heart disease, and dilated cardiomyopathy.
- Diagnosis and management are similar to that used in adults.

Further Reading

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Chapter 28

Gastroenterology

Intestinal Infection

- **Acute** gastroenteritis is the most common cause of infant mortality worldwide.
- **Viral** gastroenteritis is usually associated with small bowel disease, presenting with 5 to 10 watery, large-volume episodes per day.
  - Rotavirus: lasts 5 to 7 days; symptoms include fever, vomiting, and profuse diarrhea.
  - Adenovirus: milder than rotavirus, but lasts 8 to 12 days.
  - Norovirus, calicivirus, and astrovirus: mildest, lasting 1 to 3 days.
- **Bacterial** gastroenteritis usually starts watery; stool may become mucousy or blood-tinged.
  - Bacterial gastroenteritis may transition to colitis or dysentery.
  - Colitis/dysentery signs include frequent episodes (10–20/day); mucousy, bloody stools; and positive hemoccult test.
  - Species include *Salmonella*, *Shigella*, *Escherichia coli* (enterohemorrhagic or enteroinvasive), *Campylobacter*, *Yersinia*, and *Clostridium difficile*.
  - Enterotoxigenic *E coli* and cholera only cause watery diarrhea.
  - Treatment is largely supportive by way of oral or IV rehydration. Always treat *Shigella* and cholera. Other bacteria may be self-limited, but should be treated in the setting of outbreaks to decrease spread, or in particularly severe cases. Azithromycin or trimethoprim-sulfamethoxazole is frequently used pending stool culture result.

- **Protozoal gastroenteritis** can be dysenteric (*Entamoeba histolytica*) or consist of more chronic loose stools (eg, *Giardia*, *Cryptosporidium*, etc).
  - Treat symptomatic (dysenteric) amebiasis with metronidazole; however, metronidazole does not eradicate the ameba from the intestine. For eradication, use paromomycin or diloxanide. Eradication therapy for local personnel is not recommended; indigenous personnel will likely be quickly recolonized.
  - Treat *Giardia* with tinidazole or nitazoxanide. If those are unavailable, use metronidazole.
  - Many countries have a quinolone (eg, norfloxacin) and metronidazole combination drug that comes in a pediatric solution. It can be used to empirically treat to dysentery in the absence of diagnostics.
  - *Cryptosporidium* and other parasites can be treated with nitazoxanide, tinidazole, and others. NOTE: paromomycin, diloxanide, nitazoxanide, and tinidazole are unlikely to be available in a deployed setting.

Osmotic Diarrhea

- Osmotic diarrhea usually indicates an injury to the small bowel mucosa and can be seen transiently in postinfectious diarrhea.
- Treat by feeding with soy or other lactose-free formula until healed.
  - Rice formula is not recommended because it mainly consists of carbohydrates and lacks the protein and fat that the bowel needs to promote rapid healing and epithelial cell growth.
  - Juice is not recommended.

Allergic Colitis

- Allergic colitis is seen mostly in infants.
  - It usually presents at age 6 to 8 weeks.
  - It is often diagnosed after clinical presentation of blood-tinged, mucousy diarrhea.
  - Babies usually outgrow typical allergic colitis by 12 months of age.

- Children with allergic colitis often appear well otherwise, but can present with malnutrition, protein-losing enteropathy, or anemia.
- Skin manifestations are typically absent, especially in younger infants, because the colitis is frequently due to an immunoglobulin G-mediated allergy (rather than an immunoglobulin E-mediated one).
- To treat: remove all cow's milk protein from the patient's diet.
  - If the baby is not severely ill, try feeding with soy formula.
  - If the infant's mother can breast-feed, continue breast-feeding, but remove all cow's milk from the mother's diet.
  - If the baby is severely ill and semi-elemental based formulas are not available, continue treating with soy formula or breast-feeding with maternal milk elimination diet.
  - Semi-elemental formula: Nutramigen (Enfamil, Mead Johnson & Company, LLC, Glenview, IL) or Alimentum (Similac, Abbott Nutrition, Columbus, OH). Consider amino-acid based formulas as well.

Malabsorption

- Malabsorption disorders in infants are usually manifestations of chronic duodenal infection, such as those that occur with parasites.
- Malabsorption may also be caused by genetic disorders that lead to fat malabsorption (cystic fibrosis is the common etiology for fat malabsorption in the first year of life).
- In the second year of life, infection is still a likely cause of malabsorption, but celiac disease also becomes more prevalent.
  - Celiac disease is an autoimmune disorder that requires gluten, a byproduct of wheat-containing foods, to manifest itself (thus, it is less common in certain areas of the world).
  - Treatment is a gluten-free diet for the patient's lifetime.
- In older children showing evidence of malabsorption, infection and inflammatory bowel disease are the two most likely causes. Inflammatory bowel disease is an autoimmune disorder that is rarely seen in underdeveloped countries.

- Protein-losing enteropathy presents with diarrhea and edema and has many etiologies.
  - Begin by ruling out allergic colitis, infection, and other inflammatory conditions.
  - In remote locations, the diagnosis can be made by evidence of protein malnutrition, low serum albumin, and urinalysis that is clear of protein.
  - The differential also includes primary protein malnutrition from deficient dietary protein; a dietary history is essential in any child with diarrhea.
  - Treatment of protein malabsorption requires determining the etiology.
    - Meanwhile, use an amino acid-based formula or a formula that is as elemental as possible (eg, breast milk from a mother who has removed dairy from her diet).
    - Some children need total parenteral nutrition for nutritional rehabilitation if feeding exacerbates the symptoms.

Constipation

- Functional constipation usually begins at age 18 months to 2 years old, when toilet training begins.
- It manifests as infrequent, large, hard stools, sometimes predisposing to anal fissures.
- Encopresis (overflow of bowel movement into the underwear) or intermittent overflow diarrhea can occur in severe cases.
  - Treatment: clean out (typically administered over 2–3 days) is usually required first because megarectum tends to develop following chronic retention.
  - Administer enema once a day for 2 days, followed by bisacodyl (5 mg tablet orally [PO] or 10 mg suppository every day for 1–2 days).
    - When used in an enema or for a child dose, halve the adult size (60 cc of phosphosoda).
    - **Never give a young infant less than 6 months old or any child with a suspected rectal outlet obstruction (eg, Hirschsprung's) an electrolyte solution, such as phosphosoda enemas; this type of treatment has been reported to cause severe electrolyte disturbances (hyperphosphatemia) and death in infants.**

- Mineral oil enemas are sometimes effective (1–2 cc/kg as single dose).
- Recommended daily medications are as follows:
  - Polyethylene glycol at a dose of 1 capful mixed with water, juice, or poured on soft food, given 1 to 3 times per day; this treatment has largely replaced the other daily medications listed below and should be tried first.
  - Milk of magnesia: 1 to 2 cc/kg/day (max 60 mL daily).
  - Mineral oil: 1 to 2 cc/kg/day.
  - Lactulose: 1 to 2 cc/kg/day, up to 30 mL.

- Some organic disorders cause constipation.
  - Hirschsprung's disease usually presents with obstructive symptoms and no bowel movement in the first 24 hours of life, but can also present later in infancy.
    - Take abdominal films prior to rectal examination, flat plate then prone, cross-table lateral with hips slightly flexed (ie, "butt up").
    - These show distended loops of bowel, but also the absence of air in the area that should be the rectal vault.
    - Because rectal air will be expelled with a digital rectal examination, films must be taken first.
    - Bowel movements are usually explosive and watery, which can be documented on a digital rectal examination (in which forceful expulsion of soft stool occurs on extraction of the examiner's finger).
    - The physical examination reveals a long, tight sphincter canal.
    - Follow this with a contrast enema to rule out etiologies besides Hirschsprung's, such as microcolon and imperforate anus.
    - Confirmatory diagnosis is only made by rectal biopsy.
    - Treatment is surgical, but can be temporized by frequent rectal washings with normal saline (5–10 cc every 3 h) via a rectal tube (10–12 Fr red rubber catheter inserted a few centimeters from the anus).
  - When a newborn does not stool in the first 24 hours of life, obstructive lesions are possible, but also consider meconium plug syndrome.

        - Meconium plug syndrome is usually benign.
        - Symptoms are relieved after contrast enema or serial rectal washings.
        - Meconium plug syndrome may indicate cystic fibrosis, but is not pathognomonic.
- Anatomical defects
    - Some anatomical defects that can result in constipation include:
        - Anorectal malformations, such as imperforate anus, rectal stenosis, and anterior displaced anus.
        - Microcolon (especially in infants of diabetic mothers).
        - Obstructive intestinal lesions, such as ileal atresia.
        - Neurological disorders, such as caudal regression syndrome.
    - Treat first with oral hyperosmotic agents, such as lactulose or milk of magnesia; eventually administer enemas as needed (patients with these conditions do not have adequate sensation to have a bowel movement).

Vomiting and Gastroesophageal Reflux

- If vomiting is bilious, an upper gastrointestinal (GI) series is imperative to rule out malrotation with volvulus, duodenal atresia, or atresia of the small intestine.
- For nonbilious vomiting in an infant 4 to 6 weeks old, consider hypertrophic pyloric stenosis.
- If vomiting is chronic, consider gastroesophageal reflux disease.
    - Gastroesophageal reflux in children may present as respiratory disease (either apnea and bradycardia in infants or asthma in older children).
    - Severe vomiting with failure to thrive, lethargy, or delayed development can be a sign of metabolic disease in infancy.
- Another etiology of chronic vomiting in infants and children is peptic ulcer disease (especially if accompanied by abdominal pain), with or without *Helicobacter pylori;* and urinary tract infection, especially with hydronephrosis.

- Laboratory evaluation for chronic vomiting or vomiting causing chronic problems (such as failure to thrive, abdominal pain, etc) includes:
  - Complete blood count.
  - Erythrocyte sedimentation rate and complete metabolic panel.
  - Amylase.
  - Lipase.
  - Urinalysis and culture.
  - If possible, an upper GI series can also rule out malrotation in the presence of chronic vomiting.
- Treatment
  - Treat gastroesophageal reflux disease in children using any of the following:
    - Ranitidine: 1 to 2 mg/kg twice daily.
    - Omeprazole: 0.7 to 3 mg/kg/day (capsule can be emptied into yogurt or applesauce to encourage ingestion).
    - Over-the-counter antacids, such as aluminum hydroxide with magnesium hydroxide (1–2 cc/kg given frequently through the day with feeds; watch for changes in bowel movements).
    - Metoclopramide (0.1–0.2 mg/kg 3–4 times per day prior to a meal) may be helpful for infants as well. If possible, rule out malrotation with severe gastroesophageal reflux before adding this medication (and definitely if the emesis is bilious).
- Consider adding erythromycin as prokinetic (3 mg/kg/dose four times daily).
  - If *H pylori* is expected, the suggested antibiotics are similar to those recommended for adults, including the following:
    - Amoxicillin: 50 mg/kg/day divided twice daily.
    - Clarithromycin: 20 mg/kg/day divided twice daily.
    - Metronidazole: 20 mg/kg/day divided three times daily.
    - Proton pump inhibitors: 1 to 2 mg/kg/day at weight-appropriate doses for 2 weeks.
    - The usual choices are amoxicillin, clarithromycin, and omeprazole, but that can be altered if the patient is allergic to amoxicillin.

Gastrointestinal Bleeding

- To treat GI bleeding, first check airway, breathing, and circulation, and perform hemodynamic stabilization if bleeding is severe.
- Take a patient history and perform a physical examination to determine etiology or source of the bleeding and ongoing rate of blood losses.
- Potential laboratory examinations include complete blood count, prothrombin time or activated partial thromboplastin time, liver function panel, disseminated intravascular coagulation panel, electrolyte panel with blood urea nitrogen/creatinine, blood type and cross-match, and stool guaiac.
- If the patient has bloody diarrhea, send a stool sample for fecal leukocytes test and culture.
- Consider blood transfusion.
- Perform gastric lavage if upper GI bleeding is evident.
- Etiologies are based on age.
  - Toddlers to children of early school age: painless rectal bleeding (either hematochezia or melena) in large quantity that drops hemoglobin levels is likely Meckel's diverticulum.
    - If this is suspected, admit the patient and observe by frequently checking hemoglobin levels.
    - Radiologic diagnosis is made by Meckel's scan.
    - Treat with surgical resection of the Meckel's diverticulum.
  - In older children, significant upper GI bleeding is usually peptic disease, gastritis, or esophagitis.
    - Occult liver disease can present as upper GI bleeding from esophageal varices in children.
    - The other "at-risk" population includes patients who had omphalitis or umbilical cord catheterization complicated by portal vein thrombosis, causing portal hypertension.
  - Another relatively common presentation of rectal bleeding is allergic colitis in an infant 1 to 2 months old.
- The most common cause of lower GI bleeding in the first year of age is anal fissure. Treat using warm soaks and stool softeners.

Chronic Abdominal Pain

- Warning signs of organic disease include frequent vomiting, diarrhea, GI bleeding, weight loss or failure to gain weight normally, associated systemic symptoms, nocturnal wakening symptoms, localized pain, poor appetite, and early satiety.
- *H pylori* may cause vomiting associated with upper abdominal pain.
- Intussusception presents with severe abdominal pain that manifests as colicky pain, followed by bowel movement that may appear as melena or bright red blood.
  - The classic appearance of the stool in the late stages is described as the "currant jelly stool" due to bowel wall ischemia.
  - In younger infants and children, subjective localized pain will be absent.
    - On physical examination, tenderness can often be localized in the right lower quadrant.
    - This presentation usually occurs in children 6 months to 2 years old and is ileocolic.
  - A kidney, ureter, and bladder radiograph will show paucity of bowel gas in the right lower quadrant, and a barium enema can be diagnostic and therapeutic.
    - The risk of bowel perforation is higher during the diagnostic and therapeutic contrast enema if there has been a delay from the time of onset of symptoms; exercise caution.
    - Admit and observe the patient; there is significant risk of recurrence in the first 24 hours, and fluids and electrolytes must be managed.
    - If the enema does not reduce the intussusception, surgery will be needed for manual reduction.
    - If intussusception occurs in an older child or occurs in a less typical location, such as ileal-ileal, be wary of other types of lead points, such as polyp disease or cancer lesions (as in lymphoma).

Acute Abdominal Pain

- Omental cysts
  - Omental cysts may cause abdominal pain.
  - They be difficult to diagnose on physical examination because of the large size and fluidity of the structure.
  - Omental cysts are readily noticeable on ultrasound and computed tomography scan of the abdomen.
  - Treatment is surgical resection.
- Intraabdominal masses and tumors may cause abdominal pain.
  - Ultrasound and computed tomography scan of the abdomen are sufficient for diagnosis.
  - Masses and tumors are sometimes evident on a kidney, ureter, and bladder radiograph.
- Peptic disease, celiac disease, esophagitis, and colitis cause abdominal pain.
- Nephrolithiasis and hydronephrosis, with or without urinary tract infection, can cause severe flank pain.
- Cholelithiasis and cholecystitis are uncommon in children; however, children may have congenital lesions that predispose them to these diseases. Sickle cell and cystic fibrosis patients are also prone to these problems.

Tube Feedings

- See Chapter 36, Nursing Assessment, for advice on enteral tube feeding, and comprehensive equipment table in Appendix C for age-appropriate nasogastric tube sizes.

Chapter 29

Infectious Diseases

Ocular Infections (see also Chapter 14, Ophthalmology)

Neonatal Conjunctivitis

- Symptoms include profuse purulence or hemorrhage in the conjunctivae.
- Etiology includes *Neisseria gonorrhoeae*, *Chlamydia trachomatis*, and herpes simplex virus (HSV).
- Diagnosis
  - Gonococcal: Generally profuse, thick discharge, which may be unilateral or bilateral. Perform Gram stain and culture on chocolate agar.
  - Chlamydia: Purulence is usually thin, whitish, watery, and bilateral. Use nucleic acid amplification tests.
  - HSV: Includes a variety of presentations from simple eye redness to thick discharge. The eye may also have surrounding vesicles. Use viral culture, direct fluorescent antibody, or polymerase chain reaction (PCR). In neonates, rule out disseminated HSV by evaluating cerebrospinal fluid and liver transaminases or HSV deoxyribonucleic acid (DNA) PCR, if available.
- Treatment (if laboratory testing is not readily available, consider empiric treatment)
  - Gonococcus
    - Administer ceftriaxone (50 mg/kg intravenous [IV] or intramuscular [IM] once, with a maximum of 125 mg) or cefotaxime twice a day for 7 days if neonate is jaundiced.
    - Irrigate every 1 to 2 hours with saline.
    - Topical antibiotics are not recommended.
  - Chlamydia
    - Administer oral (PO) erythromycin (50 mg/kg/day in 4 divided doses) for 14 days, or azithromycin 20 mg/kg daily for 3 days.

  - HSV
    - Apply topical trifluridine or vidarabine for 7 to 10 days.
    - Consult an ophthalmologist, if possible.
    - In severe cases or if infection has disseminated, administer IV acyclovir 20 mg/kg/dose three times a day for 14 to 21 days.
- Universal neonatal prophylaxis: apply topical 0.5% erythromycin ointment (preferred), 1% silver nitrate, or 1% tetracycline.

Trachoma

- Symptoms include:
  - chronic, mucopurulent drainage;
  - follicular inflammation on the upper eyelid; and
  - trichiasis (scarring with lashes turned inward).
- Etiology
  - *C trachomatis* serovars A–C,
  - endemic in developing parts of world, and
  - major cause of blindness worldwide.
- Diagnosis is clinical.
- Treatment consists of PO azithromycin (20 mg/kg once; 1 g maximum dose).

Periorbital Cellulitis

- Symptoms include erythema and edema surrounding the eye.
- Etiology involves inoculation from trauma or insect bite (*Staphylococcus aureus* or group A streptococcus) or bacteremic seeding (*Haemophilus influenzae type B* [Hib] or *Streptococcus pneumoniae*).
- Diagnosis is made by clinically assessing for normal globe movement, lack of proptosis, and lack of pain with extraocular muscle use. Blood cultures should be obtained.
- Treatment consists of administering third-generation cephalosporin. Add an antistaphylococcal drug (including methicillin-resistant *Staphylococcus aureus* [MRSA] coverage) if trauma is suspected or skin is broken.
- Perform lumbar puncture if Hib is suspected or if there is evidence of meningitis.

Orbital Cellulitis

- Symptoms include:
  - periorbital edema and erythema;
  - proptosis, severe eye pain, vision loss; and
  - limitation of extraocular movement in more severe cases.
- Etiology
  - underlying bacterial sinusitis,
  - *S pneumonia*,
  - *Streptococcus pyogenes*,
  - *S aureus*,
  - *H influenzae* (nontypable),
  - *Moraxella catarrhalis*, and
  - anaerobes in older children.
- Diagnosis is clinical. Computed tomography (CT) scan may be used, if available, to assess for abscess.
- Treatment includes IV ceftriaxone and clindamycin; or ampicillin (AMP)-sulbactam and vancomycin. Consider surgical intervention if condition continues to progress 24 to 48 hours after treatment or if there is evidence of subperiosteal abscess.

Diseases of the Face and Neck

Buccal Cellulitis

- Symptoms include acute cheek edema and erythema anterior to parotid, associated with fever.
- Etiology includes Hib. Oral flora will be present if the condition is an extension of odontogenic infection.
- Diagnosis is clinical; organism can be obtained by blood culture.
- Treatment consists of administering third-generation IV cephalosporin.

Epiglottitis (see Chapter 26, Respiratory Emergencies)

Bacterial Tracheitis (see Chapter 26, Respiratory Emergencies)

Parotitis, Sialadenitis, and Mumps

- Symptoms include painful swelling of the salivary glands (parotid, sublingual, or submandibular). Fever and toxicity are present with bacterial infection.
- Etiology is viral (usually mumps, human immunodeficiency virus [HIV], or enteroviruses) or bacterial (*S aureus*, gram-negative bacilli, *S pyogenes*, *S pneumoniae*).
- Diagnosis is clinical. Bacterial infection manifests with purulent drainage from Stensen's duct. Perform Gram stain and culture.
- Treatment
  - Bacterial: hydrate and provide parenteral antibiotics (eg, ceftriaxone, AMP/sulbactam, or other broad-spectrum varieties); cannulate duct or perform surgical drainage in severe or refractory cases; cover for MRSA if cultures dictate.
  - Viral: supportive.

Parapharyngeal Abscess

- Symptoms include preceding adenitis, tonsillitis, or dental infection in children 5 years old and above; trismus; and parotid-area swelling extending below mandible.
- Etiology includes *S pneumoniae*, *S aureus*, group A β-hemolytic streptococci, and anaerobes.
- Diagnosis
  - Retropharyngeal abscess may have bulging posterior pharyngeal wall on plain film.
  - Prevertebral soft tissue swelling of greater than 7 mm at the level of the second cervical vertebra, or greater than 14 mm at the level of the sixth cervical vertebra, is suggestive.
  - Reversal of the normal cervical curvature may be present. Imaging with CT or magnetic resonance is required for definitive diagnosis.
- Treatment consists of surgical drainage and appropriate IV antibiotic therapy for primary infection (usually ceftriaxone and clindamycin).

Skin, Soft Tissue, Bone, and Joint Infections

In areas with a high prevalence of community-acquired MRSA, consider using clindamycin, trimethoprim-sulfamethoxazole (TMP/SMX), or vancomycin (IV only) when initiating empiric therapy for staphylococcal infections.

Cellulitis and Lymphangitis

- Symptoms include erythema, induration, warmth, tenderness, and lymphangitic spread (streaks).
- Etiology is most commonly *S aureus*, group A streptococcus, and Hib in unimmunized toddlers.
- Diagnosis is clinical and includes positive blood culture in less than 10% of patients, positive aspirate culture in 50%.
- Treatment consists of oral or IV antibiotics for *S aureus* and group A streptococcus (first-generation cephalosporin, antistaphylococcal penicillin, clindamycin). Rapid progression may indicate infection in deeper tissue planes, such as necrotizing fasciitis.

Cutaneous Candidiasis/Yeast Infections

- Symptoms include painful or itchy erythematous rash, usually concentrated in skin folds or covered areas (eg, diaper rash).
- Etiology is Candida species (usually *Candida albicans*).
- Diagnosis is based on clinical appearance. Erythema with sharp borders and smaller satellite lesions are frequently seen around the rash border.
- Treatment consists of one dose of fluconazole (10 mg/kg IV/PO; maximum dose of 150 mg), **OR** topical antifungals, such as clotrimazole or nystatin.

Lymphadenitis

- Symptoms include swollen lymph nodes often associated with erythema, warmth, and tenderness.
- Etiology includes *S aureus*, group A streptococcus, mycobacterial species, toxoplasmosis, and many viruses. Consider plague in endemic areas.

- Diagnosis is based on clinical appearance. Depending on location, consider throat culture, complete blood count, monospot, Gram stain, and a culture of the drainage.
- Treatment consists of empiric antibiotics against *S aureus* (including MRSA) and group A streptococcus. Surgically drain abscess, if needed. If patient does not improve, consider tuberculosis (TB), chronic viral infection (eg, HIV), and atypical mycobacteria.

Septic Arthritis

- Symptoms include pain, swelling, erythema, warmth, and joint tenderness. Pain may be referred.
- Etiology is most commonly *S aureus*, but *N gonorrhoeae* is possible if the patient is sexually active. Other etiologies include group A streptococcus, group B streptococcus (in neonates), *S pneumoniae*, *Brucella* (especially hip or sacrum), Hib (if unimmunized), and other gram negatives.
- Diagnosis is made when the following are present:
  - elevated white blood cell (WBC) count,
  - elevated erythrocyte sedimentation rate (ESR), and
  - elevated C-reactive protein (CRP).
  - Ultrasound may reveal fluid in joints.
  - Perform Gram stain and culture of joint aspirate.
- Treat as follows:
  - Drain joint (particularly the hip joint).
  - Empiric IV antibiotics should cover *S aureus* (first- or second-generation cephalosporin, antistaphylococcal penicillin; when MRSA is a concern, use vancomycin or clindamycin). In Hib, use a third-generation cephalosporin.
  - Administer ceftriaxone for *N gonorrhoeae*.
- Differential diagnosis in children includes toxic synovitis (a diagnosis of exclusion), reactive arthritis, and juvenile rheumatoid arthritis.

Osteomyelitis

- Symptoms include pain, tenderness over bone (with or without swelling), overlying erythema, warmth, and fever.

- Etiology is most commonly *S aureus*. Others include group A streptococcus, *H influenzae*, *Kingella*, *Brucella*, and mycobacteria species (including TB).
- Diagnosis: Patient will have elevated WBC count, ESR, and CRP; take radiographs of the suspected bones. If taken early, the radiographs may be normal.
- Treatment
  - Use empiric IV antibiotics against *S aureus* (first-generation cephalosporin, antistaphylococcal penicillin; alternatively, use vancomycin, or clindamycin if MRSA is a concern).
  - If patient initially presents with a high fever or appears very ill, or for patients with sickle cell disease, cover for gram-negative organisms with ceftriaxone (or similar).
  - Complete 3 to 6 weeks of antibiotics (switch to PO after 1 week or when CRP and examination are normal and compliance with oral medications is ensured).
  - Surgical debridement may be necessary if the condition is severe or if the patient fails to respond.
  - Chronic osteomyelitis may require long-term therapy (months to years).
  - If the patient fails to respond to antistaphylococcal medication, broaden coverage to include gram-negative organisms.

Pulmonary Infections

Croup (laryngotracheitis/laryngotracheobronchitis; see Chapter 26, Respiratory Emergencies)

Bronchiolitis (see Chapter 26, Respiratory Emergencies)

Pneumonia

- Symptoms include fever, tachypnea, retractions, and focal lung findings.
- Etiology
  - Bacterial: *S pneumoniae*, *H influenzae*, *S aureus*, *Mycoplasma pneumoniae*, *Chlamydia pneumoniae*, *Bordetella pertussis*, *Mycobacterium tuberculosis*, *Chlamydia trachomatis* (infants), and group B streptococcus (infants).

  - Viral: respiratory syncytial virus, influenza, parainfluenza, adenovirus, and measles.
  - Parasitic/fungal: Pneumocystis carinii/jiroveci (if the patient has HIV or is immunosuppressed or malnourished).
- Epidemiology
  - Pneumonia can occur in all ages and all seasons, and has high morbidity and mortality in children less than 5 years old.
  - Risk factors include poverty, crowding, environmental exposures, prematurity, malnutrition, immunosuppression, and lack of breast-feeding.
- Diagnosis
  - clinical,
  - radiological (take chest radiograph, if available), and
  - laboratory (cultures).
- Treatment
  - Provide supportive care (eg, IV fluids, oxygen).
  - Consider TB skin test in all children.
  - Treatment duration is 5 to 10 days for uncomplicated infection, 2 to 4 weeks for complicated or severe infection.
- Antibiotics
  - Less than 2 months old: IV AMP and gentamicin; **OR** AMP and cefotaxime.
  - Greater than 2 months old: IV ceftriaxone or AMP.
  - If atypicals are suspected (*M pneumoniae* or *C pneumoniae*), add azithromycin 10 mg/kg once, followed by 5 mg/kg/day for a total of 5 days.
  - If HIV is suspected or if the patient is severely malnourished, consider TMP/SMX.
  - If disease is nosocomial or the patient is immunosuppressed, consider broadening coverage with vancomycin, antifungals, or TMP/SMX.
  - If aspiration is the etiology, provide anaerobic coverage (clindamycin or AMP/sulbactam).
- Complications
  - Suspect complications in cases of severe pneumonia with prolonged fever, septic appearance, slow response to antibiotics, and clinical deterioration.
  - In the case of a lung abscess:

    - obtain a CT scan, if possible;
    - include anaerobic coverage; and
    - extend treatment to 3 to 4 weeks or more.
  - In the case of effusion/empyema (suspect this in patients with dyspnea and pleuritic pain):
    - Patients will exhibit dullness to percussion and decreased breath sounds.
    - Take decubitus films, CT scan, and ultrasound, if available.
    - Use a chest tube rather than thoracentesis to address large effusions, if possible.

Whooping Cough/Pertussis

- Symptoms
  - Suspect pertussis if a patient exhibits paroxysmal cough, facial petechiae, or posttussive emesis, or if patient's face turns red or blue with cough.
  - Catarrhal: patient will show mild symptoms of upper respiratory infection (URI); antibiotics may ameliorate disease and limit spread. Neonates may present with apnea.
  - Paroxysmal: patient has paroxysms of cough with inspiratory whoop, with or without posttussive emesis.
  - Convalescent: patient's symptoms wane gradually over weeks to months (usually afebrile); can last 6 to 10 weeks or longer.
- Most severe in children less than 6 months old who may present with apnea or elevated WBC count with lymphocytosis.
- Epidemiology
  - *B pertussis*, *Bordetella parapertussis*.
  - Humans are the only hosts.
  - Transmitted via aerosolized droplets.
  - Adolescents and adults are important infectious sources; incidence is increased in conditions of close contact.
- Diagnosis: clinical (culture or PCR, if available).
- Treatment
  - Administer macrolides (azithromycin, erythromycin, clarithromycin). Use macrolides with caution in infants less than 2 months old due to concerns of pyloric stenosis.
  - Provide supportive therapy (eg, IV fluids, rest, oxygen).

- Prophylaxis and control can be achieved by:
  - immunization, and
  - postexposure prophylaxis (same dose and duration as treatment).
    - Erythromycin: 40 to 50 mg/kg/day divided four times daily for 14 days (maximum 2 g/day; estolate salt is better tolerated).
    - Azithromycin: 10 to 12 mg/kg once daily for 5 days (do not step down doses on days 2 to 5; maximum of 600 mg/day).
    - Clarithromycin: 15 to 20 mg/kg/day, divided twice daily for 7 days (maximum 1 g/day).
    - TMP/SMX: if the patient cannot tolerate erythromycin, give 8 mg/kg/day TMP component twice daily for 14 days (contraindicated in infants less than 2 months old because of the risk for kernicterus).

Tuberculosis

- Symptoms: fever, weight loss/failure to thrive, cough, night sweats, chills.
- Extrapulmonary findings may include meningitis, lymphadenitis, and involvement of bones, joints, skin, and middle ear or mastoid.
- Epidemiology includes *M tuberculosis*. Incidence is increased in populations with high HIV rates.
- Diagnosis in the low and moderate resource setting is difficult. Tuberculin skin tests are unreliable predictors of TB diseases due to high rates of latent infection and a high rate of anergy in high-risk groups (malnourished and HIV) as well as those with active TB disease.
- Use chest radiograph to evaluate for evidence of active pulmonary disease. Careful clinical evaluation may also detect extrapulmonary manifestations of tuberculosis, such as vertebral TB or TB lymphadenitis.
- Sputum specimens are often difficult to obtain in young children but should be pursued. Acid-fast staining is widely available but has an unreliable sensitivity in children. Sputum culture, though more sensitive, is often not widely available. In some regions, World Health Organization (WHO) and

ministry-of-health-supported referral programs have rolled out the Xpert MTB/RIF (Cepheid, Sunnyvale, CA), a PCR assay designed for use in low-resource settings that can rapidly detect the presence of TB in sputum smears as well as genes coding for rifampin resistance (which predicts multidrug resistance).

- Treatment should be consistent with the host-nation ministry or department of health guidelines. Additional resources for WHO diagnosis and treatment guidelines are available at the end of this chapter.
- Due to the resources required, long duration of care, and risk of fostering resistance, deployed military forces should be reticent to initiate treatment of TB in local populations unless there is a capacity to transition care to a functioning ministry of health or nongovernmental agency TB program.
- Active disease (see drug dosages below)
  - Pulmonary/extrapulmonary (except meningitis) in an HIV-negative child:
    - 2 months of isoniazid plus rifampin plus pyrazinamide, **followed by**
    - 4 months of isoniazid and rifampin.
  - Pulmonary/extrapulmonary (except meningitis and osteoarticular) in an HIV-positive child or where local rates of isoniazid resistance are elevated:
    - 2 months of isoniazid plus rifampin plus pyrazinamide plus ethambutol. Ethambutol can cause optic neuritis, so avoid use in young children unless they can cooperate with tests for visual acuity and color blindness.
    - 4 months of isoniazid and rifampin.
  - For meningitis and osteoarticular TB:
    - 2 months of isoniazid plus rifampin plus pyrazinamide plus ethambutol.
    - 10 months of isoniazid and rifampin.
  - Steroids are indicated for TB meningitis, pericardial TB, and airway obstruction due to TB.
    - Dexamethasone 0.3 to 0.4 mg/kg/day (IV until the patient starts accepting PO, at which time tablets can be used) or prednisolone or prednisone 2 mg/kg/day (maximum dose 60 mg). Total duration is 6 to 12 weeks based on disease severity and includes a 2-week taper.

        - In active pulmonary disease, the WHO does not recommend follow-up chest radiographs for those patients who are clinically responding well. Resolution of radiographic changes will be slow.
    - Drug dosages:
        - Isoniazid: 10 to 15 mg/kg/day (maximum 300 mg/day) **OR** 20 to 30 mg/kg three times weekly.
        - Rifampin: 10 to 20 mg/kg/day (maximum 600 mg/day) **OR** 10 to 20 mg/kg three times weekly.
        - Pyrazinamide: 30 to 40 mg/kg/day (maximum 2 g/day).
        - Ethambutol: 20 mg/kg/day (maximum 2.5 g/day).
- In settings with a high HIV prevalence, TB-infected children should not be treated with intermittent regimens (ie, two or three times per week dosing). During the continuation phase of therapy, three-times-per-week regimens can be considered for children confirmed to be HIV-uninfected *and* living in settings with well-established, directly observed therapy programs.
    - Routine laboratory checks are not recommended by the WHO. Assess transaminases in children with hepatomegaly, jaundice, right upper quadrant tenderness, or prolonged nausea and vomiting.
    - Provide B6 (pyridoxine) supplementation for individuals who are malnourished or HIV positive to prevent isoniazid-induced neuritis, 1 to 2 mg/kg/day (maximum 50 mg/day).
    - Children with TB likely acquired it from an adult, so investigate all who have had contact with the infected child, looking for the index case as well as for other infected children.
    - WHO recommendations for assessing case contacts in a low- or moderate-resource setting call for clinical assessment for illness but do not require a chest radiograph or skin test.
    - Preventive therapy for latent TB infection with 6 months of isoniazid is recommended by WHO for contacts of TB cases who are infected with HIV, or who are under 5 years old.

Urinary Tract Infections and Pyelonephritis

- Symptoms include fever, irritability, foul-smelling or discolored urine, urinary frequency and urgency, dysuria, emesis, and diarrhea.

- Urinary tract infection should be considered in any child less than 2 years old with unexplained fever, as children this young cannot verbalize dysuria complaints.
- Etiology: Gram-negative enteric organisms, especially *E coli*.
- Diagnosis is made by urinalysis, preferably with corresponding culture.
  - Specimens obtained by bag are useful for urinalysis, but not for culture because of skin contamination. If culture is not available, use a urine dipstick or microscopy.
  - Leukocyte esterase test on a urine dipstick is sensitive, but not specific; nitrite is specific for urinary tract infection, but not sensitive.
  - Greater than 10 WBCs per high-powered field on microscopy indicates pyuria.
  - Bacteria are also noted.
- Treatment consists of standard first-line therapies in the nontoxic child (7-day course):
  - Amoxicillin (40 mg/kg/day).
  - TMP/SMX (10 mg/kg/day of TMP) or cefixime (8 mg/kg/day every day).
  - Reevaluate in 1 to 2 days.
  - If the child appears toxic, IV or IM third-generation cephalosporin or an aminoglycoside are preferred.
- Follow-up and prophylaxis
  - If possible, evaluate anatomy with renal ultrasound.
  - If it is a recurrent infection, consider prophylactic antibiotics (amoxicillin or TMP/SMX at half the usual daily dose, given at bedtime) and further evaluation for reflux with voiding cystourethrogram.

Diarrhea in a Humanitarian-Assistance Setting

- Symptoms include the following:
  - three or more loose or watery stools per day,
  - acute diarrhea that starts suddenly and is generally self-limited after several days, or
  - persistent diarrhea that starts like acute diarrhea but lasts 14 days or more.
- Etiology
  - Diarrhea is the major cause of morbidity and mortality among children worldwide.

- WHO recognizes acute watery diarrhea and dysentery as the two basic types of acute diarrhea.
  - Acute watery diarrhea in children in low-income countries may be caused by rotavirus, *Cryptosporidium*, *Aeromonas*, adenovirus, and *E coli*, as well as classic dysentery pathogens, such as *Salmonella* and campylobacter. When a patient presents with a high volume of watery stools with flecks of mucous (rice-water stools), rule out cholera.
  - Dysentery is defined as bloody, mucoid diarrhea, and is usually caused by gram-negative bacteria (*Shigella*, *Campylobacter*, *Salmonella* species, and rarely, *Clostridium difficile*). Shiga-toxin producing *E coli*, associated with hemolytic-uremic syndrome, are rare in low-income countries.
- Almost all these agents are transmitted by ingesting contaminated food or water and by person-to-person spread; contact precautions are encouraged.

- Diagnosis: Use clinical diagnosis and empiric treatment for most cases.
  - Most cases in infants are of viral etiology (rotavirus). Confirm initial cases of cholera and bacillary dysentery microbiologically, if possible.
  - WHO case definitions for cholera:
    - any person older than 5 years with severe dehydration or death due to watery diarrhea, or
    - any person older than 2 years with watery diarrhea in an area with a cholera outbreak.
- Treatment (derived from WHO guidelines; assumes limited resources and limited or no laboratory support):
  - assess dehydration (ie, none, some, severe);
  - prevent dehydration by increasing fluid intake (use oral rehydration solution [ORS] or breast milk);
  - treat dehydration;
  - provide nutritional support and encourage feeding, support breast-feeding;
  - use antibiotics selectively;
  - avoid antimotility agents; and
  - provide empiric treatment.

    - If the patient is not dehydrated, increase fluid intake to more than the usual amount.
    - If the patient exhibits some dehydration, give ORS until skin turgor returns to normal and thirst abates; start with 75 mL/kg in first 4 hours.
    - In cases of severe dehydration, use IV fluid therapy.
    - Use a nasogastric tube if an IV cannot be placed within 30 minutes.
    - Start ORS as soon as the patient can tolerate it.
    - Give 30 mL/kg IV bolus, then another 70 mL/kg IV over the next 4 to 6 hours.
    - Zinc supplementation for 10 to 14 days will mitigate current illness and decrease the incidence of subsequent episodes (10 mg a day for children younger than 6 months old, 20 mg a day for those older than 6 months; check the available zinc salt preparation for zinc content).
    - Treat with an antibiotic if dysentery is likely (know local resistance patterns if possible).
- Antibiotics are not recommended for use in children living in low-resource settings with acute watery diarrhea not due to cholera. WHO guidelines for empiric therapy of dysentery:
    - give ciprofloxacin 500 mg PO bid for 3 days (adults), 15 mg/kg PO bid for 3 days (off-label use for pediatric patients). Significant resistance is developing, especially in Southeast Asia; **OR**
    - give azithromycin 10 mg/kg PO for 3 days.
    - Resistance rates to TMP/SMX and AMP make them poor empiric choices.
    - Antibiotics will shorten the duration of cholera symptoms.
        - In large outbreaks, reserve antibiotics for severe cases.
        - Administer one dose of doxycycline (300 mg PO; WHO guidelines recommend this as off-label use for all patients).
    - For patients with persistent diarrhea, the priority is to improve nutritional intake and provide micronutrient supplementation (zinc). In cases of dysentery, two courses of antibiotics should be prescribed before empiric therapy for amoebiasis. Empiric therapy for giardiasis may be considered for persistent nonbloody diarrhea.

- Amoebiasis: symptoms include abdominal pain, fever, and diarrhea (usually bloody or mucoid). Right upper quadrant abdominal pain may represent amebic abscess.
  - Etiology: *Entamoeba histolytica*.
  - Diagnosis: Identify trophozoites or cysts on stool sample. Rapid antigen tests may be available.
  - Treatment: Give metronidazole for dysentery and abscesses. Administer diloxanide, iodoquinol, or paromomycin to eradicate cysts from stool. For endemic populations, eradicating cysts from stools is not indicated. Chlorinating water will not kill *Entamoeba*; boil water for 1 minute.
- Giardiasis
  - Etiology: *Giardia intestinalis* (formerly *Giardia lamblia*).
  - Diagnosis: Microscopic identification of trophozoites or cysts in stool. Rapid antigen test may also be used.
  - Treatment: Administer metronidazole, tinidazole, imidazole, or nitazoxanide. Paromomycin can be used for pregnant women. Chlorinating water will kill *Giardia*; boil water for 1 minute.

Systemic Conditions

Sepsis and Meningitis

- Symptoms: The clinical case definition of meningitis is sudden onset of fever (greater than 38°C) and one of the following:
  - neck stiffness in older children,
  - altered consciousness, or
  - other meningeal sign, such as:
    - Kernig sign: flex the patient's knees and the neck bends in response.
    - Brudzinski sign: flex the patient's neck and the knees bend in response.
  - Petechial or purpural rash.
  - In patients younger than 1 year old, meningitis is suspected when fever is accompanied by a bulging fontanel.
  - *Neisseria meningitidis* also causes meningococcal septicemia (severe disease with signs of acute fever, purpura or petechiae, and shock). Though less common, the case fatality rate is high.

- Etiology: *N meningitidis*, *S pneumoniae*, and Hib account for more than 80% of all cases of bacterial meningitis and sepsis in unimmunized populations.
- Diagnosis is made by blood culture. Lumbar puncture should be done as soon as meningitis is suspected and before starting antimicrobial treatment, if possible.
  - In bacterial meningitis, cerebrospinal fluid is usually cloudy or purulent (but may be clear or bloody).
  - In malaria-endemic areas, thick and thin smears of blood should be made to differentiate meningitis from cerebral malaria.
- Treatment
  - If bacterial meningitis is suspected, antibiotic treatment should be started immediately after a lumbar puncture without waiting for the results; treatment should not be delayed if lumbar puncture cannot be performed in a timely manner (Table 29-1).
  - Viral meningitis is rarely serious and requires supportive care, but a lumbar puncture is necessary to differentiate it from bacterial meningitis.
  - During epidemics of *N meningitidis* among refugees or displaced populations, a single-dose IM regimen of oily chloramphenicol can be considered.
    - Oral chloramphenicol also effectively penetrates the central nervous system.
    - Single-dose ceftriaxone IM or IV (100 mg/kg, maximum 4 g) is equivalent to a single dose of oily chloramphenicol.
  - Chemoprophylaxis of local civilian contacts is often not recommended in emergency situations; however, exposed healthcare workers should receive prophylaxis if meningococcus is suspected or confirmed. Administer:
    - Rifampin: 10 mg/kg, maximum 1,200 mg, every 12 hours for 2 days.
    - Ceftriaxone: single dose, 125 mg IM for those up to 14 years old, 250 mg for those older than 15 years.
    - Ciprofloxacin: single dose, 500 mg PO for those older than 18 years.

Table 29-1. Empiric Therapy for Bacterial Meningitis and Sepsis in Developing Countries

Patient Group	Likely Etiology	Treatment	Duration of Therapy
Immunocompetent children < 2 mo old	Group B streptococcus *Escherichia coli* *Listeria* *Salmonella* spp	Ampicillin 200–300 mg/kg/day ≤ 7 days ÷ q8h; > 7 days ÷ q6h **PLUS** Gentamicin 2.5 mg/kg q12h **OR ADD** Cefotaxime 50 mg/kg q8h	3 wk
2 mo–18 y old	*Haemophilus influenzae* *Streptococcus pneumoniae* *Neisseria meningitides* *Salmonella* spp	Ceftriaxone 100 mg/kg q24h (if resistant *Streptococcus pneumoniae* is present, add vancomycin 40 mg/kg/day, divided q6–8h)	*Haemophilus influenzae*: 10 days *Streptococcus pneumoniae*: 10–14 days *Neisseria meningitidis*: 7 days *Salmonella* spp: 21 days
Neurosurgical problems and head trauma	*Staphylococcus aureus* *Staphylococcus epidermidis* Gram-negative organisms *Streptococcus pneumoniae*	Vancomycin and a third-generation cephalosporin	Minimum 3 wk

Acute Rheumatic Fever

- Symptoms: Most commonly presents with arthritis or carditis.
- Etiology: Inflammatory process occurring after pharyngitis due to certain group A beta-hemolytic streptococci types.
  - In developed countries, there is well-known association between acute rheumatic fever and streptococcal pharyngitis. In developing countries, the association is less clear; fewer than two-thirds of patients remember having a sore throat in the months before presenting.
  - The disease is common among children aged 6 to 15 years old, rare in infants and preschool-aged children, and may occur in adults.
- Diagnosis
  - Evidence of recent streptococcal infection is required (positive throat culture or rapid streptococcal test), recent scarlet fever, or positive antibodies (antistreptolysin O or deoxyribonuclease B).
  - The diagnosis is made using the revised Jones Criteria (see Chapter 27, Cardiology, for carditis discussion, and Table 27-1); the patient must meet two major criteria **OR** one major and two minor criteria (chorea and recurrent acute rheumatic fever do not require minor criteria for diagnosis).
- Treatment
  - Penicillin V 250 mg PO bid for 10 days, or administer benzathine penicillin G (0.6 to 1.2 million units IM).
  - Administer aspirin (initially 80 to 100 mg/kg/day in four doses, decreased to 10 to 15 mg/kg/dose when afebrile) or naproxen (15 to 20 mg/kg/day in two doses).
  - Preventing recurrence includes administering benzathine penicillin G 25,000 units/kg IM every 3 to 4 weeks (maximum of 1.2 million units/dose). Alternatively, use penicillin VK 250 mg PO bid, **OR** erythromycin 250 mg PO bid for penicillin-allergic patients.
  - Recommendations for secondary prophylaxis are to continue for 10 years after the last attack, or to age 21 to 25 years, whichever is longer. In the presence of severe residual heart valve disease, prophylaxis is life-long.

Commonly used oral and IM antibiotics can be found in Tables 29-2 and 29-3.

Table 29-2. Common Oral Liquid Antimicrobial Medications Used in Children

Generic Name	Strength (mg/mL)	Average Dose (mg/kg/day)	Interval (h)	Maximum Dose
Amoxicillin	25, 40, 50, 80	Infants < 3 mo old: 20–30	12	2–3 g/day
		> 3 mo old: 25–50	8–12	
		Acute OM due to resistant *Streptococcus pneumoniae*: 80–90	12	
Amoxicillin + clavulanic acid	25, 40, 50, 80 AMX	Infants < 3 mo old: 30 AMX component	12	Use 25 mg/mL (AMX component) formulation for infants < 3 mo old
		Children < 40 kg: 25–45 AMX component	8–12	Use 4:1 (AMX:CA) formulation (25 or 50 mg AMX/mL) with tid dosing regiment
	120 AMX	> 3 mo old **and** > 40 kg with multidrug-resistant pneumococcal OM 80–90 AMX component	12	Use 7:1 (AMX:CA) or ES formulation for bid dosing regimen to avoid higher dose of CA
Azithromycin	20, 40	**URI and OM** in children > 6 mo old: 10 on day 1, followed by 5 on day 2–5	24	500 mg/day for day 1; 250 mg/day for days 2–5
		OM: 10 for 3 days	24	500 mg/day
		or 30 × 1 single dose		1,500 mg/day
		Pharyngitis in children > 2 y old: 12 for 5 days	24	500 mg/day

(**Table 29-2** *continues*)

(**Table 29-2** *continued*)

Generic Name	Strength (mg/mL)	Average Dose (mg/kg/day)	Interval (h)	Maximum Dose
Cephalexin	25, 50	25–100	6	4 g/day
Clarithromycin	25, 50	15	12	1 g/day
Clindamycin	15	10–30	6–8	1.8 g/day
Nitrofurantoin	5	Children > 1 mo old: 5–7 UTI prophylaxis: 1–2	6 24	400 mg/day 100 mg/day
Penicillin V potassium	25, 50	25–50	6–8	3 g/day
Sulfamethoxazole + trimethoprim	8 TMP + 40 SMX	Children > 2 mo old: 6–12 TMP component Serious infection in children > 2 mo old: 15–20 TMP component	12 6–8	160 mg TMP component/dose
Sulfasoxazole	100	Children > 2 mo old: 75 for initial dose, then 120–150	4–6	6 g/day

AMX: amoxicillin
bid: twice daily
CA: clavulanic acid
ES: extra strength
OM: otitis media
SMX: sulfamethoxazole
tid: three times daily
TMP: trimethoprim
URI: upper respiratory infection
UTI: urinary tract infection

Table 29-3. Common Intramuscular Antimicrobial Medications Used in Children

Drug Name	Concentration (mg/mL)	Dosage Range (mg/kg/day)	Interval (h)	Maximum Dose	Change Dose/Interval Due to Renal Dysfunction	Comments
Ampicillin	250	50–400	6	12 g/day	Yes	3 mEq Na^+/1 g ampicillin; use within 1 h of reconstitution
Cefazolin	225 or 330*	40–100	6–8	6 g/day	Yes	2 mEq Na^+/1 g cefazolin
Cefepime	280	50–150	8	2 g/dose, 6 g/day	Yes	No dosage adjustment for burn patients
Ceftriaxone	350	50–100	12	2 g/dose, 4 g/day	No	3.6 mEq Na^+/1 g ceftriaxone May cause primary cholelithiasis, nephrolithiasis, and hemolytic anemia; gallstones resolve after discontinuation Not recommended for neonates with hyperbilirubinemia
Gentamicin	40	2.0–3.5 or 5.0–7.5	8 or 24	According to serum levels	Yes	Peak concentration 4–12 μg/mL (2–3 times higher with once-daily dosing regimen) Trough concentration 0.5–2 μg/mL Contains sulfites, which may exacerbate asthma symptoms May cause cochlear and/or vestibular ototoxicity

*This concentration is only approved for use with the 1-g vial.

Miscellaneous and Tropical Diseases

Diphtheria

- Symptoms range from a moderately sore throat to toxic, life-threatening diphtheria of the larynx or of the lower and upper respiratory tracts.
- Throat may be covered by a grey membrane and the patient may have a "bull neck" appearance from local edema of the neck.
- Nasal mucosa is generally markedly inflamed.
- Disease is often complicated by myocarditis (rhythm disturbance due to toxin) and neuritis (toxic damage to peripheral nerves).
- Can be fatal; 5% to 10% of diphtheria patients die, even if properly treated (untreated patients die in greater numbers).
- Untreated patients are infectious for 2 to 3 weeks.
- Etiology is *Corynebacterium diphtheria*. In several developing countries (particularly Eastern Europe and Asia), diphtheria is the leading cause of pharyngitis in unimmunized children during an outbreak. It is transmitted by the spread of large droplets.
- Diagnosis is clinical and made by culture. A probable case definition according to WHO is as follows:
  - recent (within 2 weeks) contact with an individual confirmed contaminated,
  - diphtheria endemic to region,
  - stridor,
  - swelling/edema of the neck,
  - submucosal or skin petechiae,
  - toxic circulatory collapse,
  - acute renal insufficiency, and
  - myocarditis and motor paralysis 1 to 6 weeks after onset.
- Treatment is as follows:
  - Administer equine diphtheria antitoxin (20,000 to 100,000 units, consider test dose prior to treatment) and penicillin or erythromycin.
  - Obtain cultures before giving antibiotics.
  - Monitor contacts closely for disease development.

- Provide prophylaxis to contacts via 600,000 units penicillin (IM) in those younger than 6 years, 1.2 million units (IM) in those 6 years and older.

Human Immunodeficiency Virus and Acquired Immunodeficiency Syndrome

In deployment settings, it is impossible to properly administer antiretroviral therapy. In underdeveloped countries, the rates of HIV may be very high, and the provider should always be suspicious that an ill or malnourished patient is infected.

- Symptoms
  - recurrent or severe pneumonia in infancy (pneumococcus, tuberculosis, and *Pneumocystic carini/ jiroveci)*;
  - generalized lymphadenopathy;
  - enlarged, nontender parotitis;
  - failure to thrive;
  - mucocutaneous candidiasis; and
  - recurrent sepsis.
- Diagnosis is made based on serology, viral load, and clinical appearance.
- In the absence of antiretroviral therapy, treatment is supportive and may also include chemoprophylaxis for opportunistic infections with TMP/SMX or targeted therapy.

Japanese Encephalitis

- Symptoms include headache, fever, meningeal signs, stupor, disorientation, coma, tremors, paresis (generalized), hypertonia, and loss of coordination.
  - Japanese encephalitis cannot be distinguished clinically from other central nervous system infections.
  - Severe infections are marked by acute onset, headache, high fever, meningeal signs, and coma.
- Etiology:
  - Acute, inflammatory, mosquito-borne disease involving the brain, spinal cord, and meninges.
  - Common and usually asymptomatic.
  - Case fatality rate among individuals with clinical disease is 25% to 50%.

  - Infants and the elderly are most susceptible to severe disease.
  - Occurs in east, southeast, and southern Asia.
  - Especially associated with rice-growing areas and exposure to pigs.
- Diagnosis: demonstration of specific immunoglobulin M in acute-phase serum or cerebrospinal fluid.
- Treatment is supportive.
- Prophylaxis and control
  - Use protective clothing and repellents to avoid exposure to mosquitoes.
  - Screen sleeping and living quarters.
  - House pigs away from living quarters.
  - Effective vaccines are available.

Leptospirosis (Weil's disease)

- Most infections have mild to moderate nonspecific symptoms of fever, headache, and myalgias. Severe disease presents with abrupt onset of chills, high fever, jaundice, and renal disease (proteinuria, hematuria, azotemia). Petechiae, purpura, or pulmonary hemorrhage may also occur.
- Death occurs in 5% to 10% of patients with severe disease.
- Conjunctival suffusion, hemorrhage, ocular pain, photophobia, and intense headache may be other clues to diagnosis.
- Acquired from contact with water or soil contaminated with urine or tissues of infected animals (often rats, dogs, and cats).
- Diagnosis is typically empiric in most low-resource settings, but may be made by finding the spirochetes of *Leptospira* in the blood and urine (culture, PCR) or with acute and convalescent serologies.
- Treatment with penicillin (IV if disease is severe) and/or doxycycline during the first week of illness will shorten the disease duration.

Lyme Disease

- *Borrelia* species carried by *Ixodes* ticks found throughout Europe, parts of Asia, and pockets of the United States.
- Transmission is via the bite of infected ticks and generally requires the tick to be attached for at least 36 hours.

- Symptoms: Lyme disease is categorized into three phases, characterized by local disease (Bull's eye rash, see Chapter 34, Dermatology, Figure 34-6) as well as early and late disseminated phases. Meningitis and nerve involvement are more common with European strains.
- For a complete review of the symptoms, diagnosis, and treatment for each phase, please see the American Lyme Disease Foundation's website (http://www.aldf.com/raad.shtml) or the Medscape webpage addressing Lyme disease (http://emedicine.medscape.com/article/330178).
- Of note, US antibody detection methods will not diagnose Eurasian Lyme strains. A C6 peptide or locally obtained diagnostics are required for these strains.
- Prophylaxis: The risk of infection increases with the duration of tick attachment. If a deer tick is found and removed, and if the tick has been attached for 36 hours or is engorged, a single dose of 200 mg of doxycycline administered within the 72 hours after removal may reduce the risk of Lyme disease.

Malaria

- *Plasmodium falciparum*
  - Symptoms include:
    - anemia that may be severe (hemoglobin less than 5 gm/dL), particularly in nonimmune and pregnant patients;
    - hyperparasitemia (more than 5% of red blood cells infected on smear);
    - hyperthermia (body temperature above 41°C);
    - hypoglycemia and acidosis;
    - cerebral malaria, marked by seizures or coma (more common in children, with mortality rate of 15% to 30%);
    - renal failure;
    - pulmonary edema; and
    - diarrhea (common presenting sign in children).
    - *Plasmodium vivax* symptoms include cyclic fevers and chills and splenic rupture (late manifestation).
    - *Plasmodium malariae* and *Plasmodium ovale* symptoms include few complications due to low-level parasitemia. *P malariae* has been associated with immune complex glomerulonephritis.

- The WHO strongly recommends that parasitologic diagnosis of malaria be made prior to treatment to conserve resources and reduce expansion of drug resistance resulting from indiscriminate use. In high-transmission settings (eg, much of sub-Saharan Africa), empiric therapy for children under 5 years of age with fever can be offered when diagnostic tests are not otherwise available. While microscopy has been the traditional means of diagnosing malaria, outside of clinical trials with expert microscopists, experience has shown that in field use, rapid diagnostic tests are typically more sensitive and specific than blood smears. Some rapid diagnostic tests only test for *P falciparum* and will miss *P vivax* and other species. Although US-based practice is to perform three rapid diagnostic tests with smear microscopy backup, common practice in endemic regions is to perform a single test.
- Treatment medications are the same as for adults and are based on the infecting species, possible drug resistance, and severity of disease.
  - Use IV therapy only for severe disease.
    - Artesunate: 2.4 mg/kg/dose IV at 0, 12, 24, and 48 hours. This is the WHO first-line therapy, it is currently only available in the United States under an investigational new drug protocol from the US Centers for Disease Control and Prevention (CDC).
    - Quinidine gluconate: 10 mg/kg loading dose (maximum 600 mg) by IV infusion over period of 1 to 2 hours. Give the first 2 mg/kg as a test dose with continuous electrocardiogram monitoring for idiosyncratic prolongation of QRS or arrhythmias. Watch for hypoglycemia and hypotension. Follow loading dose with continuous infusion of 0.02 mg/kg/min to keep serum levels at 3 to 7 mg/L. This medication is not recommended by the WHO, but may be the only parenteral antimalarial medication available to deployed forces.
    - Transition to an oral regimen when parasitemia is less than 1% or patient is able to take oral medication.
  - Oral therapy

- Plasmodium with no resistance noted (most nonfalciparum species worldwide; falciparum in Central America and the Caribbean):
  - Chloroquine phosphate: 10 mg base/kg (PO; maximum 600 mg base) initially, then 5 mg base/kg (PO; maximum 300 mg base) at 24 and 48 hours.
- Plasmodium with known chloroquine resistance noted:
  - Artemisinin-based combination therapy is the WHO first-line approach. One of the most widely used regimens, and one licensed by the US Food and Drug Administration, is artemether-lumefantrine (20 mg /120 mg). First dose at time 0 and then second dose 8 hours later; then 1 dose twice daily for a total 6 doses over 3 days. Dosages by weight: 5 to 15 kg: 1 tablet per dose; 15 to 25 kg: 2 tablets per dose; 25 to 35 kg: 3 tablets per dose; 35 kg and above: 4 tablets per dose).

OR

  - Quinine sulfate: 25 mg/kg/day (PO; maximum 2,000 mg), divided three times daily for 3 to 7 days.

AND one of the following:

  - Tetracycline: 20 mg/kg/day (PO; maximum 750 mg) divided 4 times a day for 7 days for children older than 8 years.

OR

  - Clindamycin: 30 mg/kg/day PO divided 3 times a day for 5 days.

OR

  - Atovaquone/proguanil is highly effective but not recommended for treatment on a wide scale in endemic regions due to concerns of rapid resistance emergence. Mefloquine can also be used but is not recommended as a first-line drug due to the high rate of adverse effects.

- Consult entomology teams for vector control methods.
- Chemoprophylaxis is not recommended for local populations in endemic regions.
- Use permethrin-treated bed nets.

Measles

- Measles (rubeola) has played a significant role in situations involving displaced persons. It can lead to high mortality in unimmunized individuals, particularly those who are malnourished and very young.
- Symptoms include fever, cough, coryza, conjunctivitis, Koplik spots, and cephalocaudal progressive rash.
- Treatment involves recognizing the clinical disease spectrum, immunizing, and treating.
  - Immunization should target malnourished children in displacement situations and those between 6 months and 5 years old, with an emphasis on the youngest children.
  - Rubeola will often unmask vitamin A deficiency; prophylactic supplementation should occur as follows:
    - Less than 12 months old: 100,000 IU (PO) once daily for 2 days.
    - Older than 12 months: 200,000 IU (PO) once daily for 2 days.
- Complications and associated findings:
  - cervical adenitis,
  - mesenteric issues (abdominal pain, appendicitis),
  - upper respiratory tract issues (otitis media, mastoiditis, oral ulcers),
  - lower respiratory tract issues (croup, bronchiolitis, pneumonia),
  - bacterial superinfection,
  - central nervous system issues (encephalitis),
  - malabsorption/malnutrition (significant cause of mortality; treat malnutrition aggressively), and
  - ocular issues (xerophthalmia/ulcerating keratomalacia in those who are vitamin-A deficient).
  - If complications are present, a third dose of vitamin A should be given at 2 to 4 weeks after the second dose is administered.
- Treat pyogenic complications with antibiotics.

Polio

- Symptoms

  - More than 95% of cases are asymptomatic.
  - Others have nonspecific URI.
  - A small percentage has aseptic meningitis.
  - 0.1% to 2% will develop flaccid paralysis.
- Etiology: Poliovirus (enterovirus) types 1, 2, and 3. Polio is still endemic in parts of Africa and Asia, and there have been recent epidemics in Afghanistan and Pakistan.
- Diagnosis is made by viral culture of stool (best), urine, pharynx, or cerebrospinal fluid (best if done within 14 days of onset of illness) and serology.
- Treatment is supportive.
- Prophylaxis and control consists of vaccinating susceptible individuals and identifying all known cases and contacts for outbreak control. Reporting to public health officials is vital.

Viral Hemorrhagic Fevers Due to Arenaviruses and Filoviruses

- The survival of viral hemorrhagic fevers due to arenaviruses and filoviruses is typically dependent on an animal or insect host, called the natural reservoir.
- The more common viral hemorrhagic fevers include Ebola, Marburg, dengue, yellow fever, Lassa fever, and hantavirus.
- For a complete list of viral hemorrhagic fever pathogens, their areas of distribution, vectors, incubation periods and modes of transmission, see the CDC website on viral hemorrhagic fevers (http://www.cdc.gov/ncidod/dvrd/spb/mnpages/dispages/vhf.htm).
- The term "hemorrhagic fevers" is often used to a describe a severe multisystem syndrome associated with capillary leak or frank signs of bleeding and is applied to members of the arenavirus, filovirus, bunyavirus, and flavivirus families.
  - These are severe, life-threatening infections that begin with nonspecific symptoms of fever, myalgias, vomiting, and diarrhea, which may progress to petechial or purpuric rashes. Frank hemorrhage may also occur. Altered mental status is a late finding.
  - Patients rarely die of blood loss; rather, they die from shock related to dehydration, third-spacing of intravascular fluid, or secondary sepsis.

- Human cases or outbreaks of hemorrhagic fevers occur sporadically and are not easily predicted. Lassa fever is associated with a rodent reservoir. Fruit bats have been implicated as a reservoir for Ebola and Marburg; nonhuman primates and other forest-dwelling mammals have also been infected and may transmit the disease to humans who hunt, butcher, or consume undercooked meat from these animals.
- Following single-case infections from animals, nosocomial spread within medical facilities or related to funerals serve as amplifying events.
- Primary prevention includes:
  - Avoidance or control of reservoir hosts (Lassa).
  - Avoiding consumption of fruit that has been fed upon by fruit bats or "bush-meat" from susceptible animals.
  - Appropriate use of infection prevention and control procedures in healthcare settings (Ebola and Marburg).
- Outbreak control involves:
  - Rapid case identification.
  - Implementation of expanded infection control procedures specific to hemorrhagic fevers.
  - Special precautions for safe burial; however, these conflict with cultural norms in endemic regions and require close coordination with community leaders to garner support.
  - Notifying public health authorities to mobilize a broader response (critically important).
- There is no cure or established drug treatment for Ebola or Marburg, although experimental treatments are being studied as part of the recent Ebola outbreak in West Africa. Current management strategies include:
  - Intensive fluid and electrolyte support.
  - Treatment of comorbid infections due to malaria or bacteremia.
  - Symptomatic management of pain and fever.
  - Ribavirin for Lassa fever cases.
- Clinicians managing cases of Lassa, Ebola, or Marburg should consult current WHO and CDC treatment guidelines for details of current management recommendations.

Dengue and Dengue Hemorrhagic Fever

- Symptoms of dengue include acute onset fever lasting 3 to 5 days, intense headache, retro-orbital pain, myalgias, arthralgias, anorexia, and rash. Petechiae and epistaxis are occasionally seen in otherwise mild cases but raise concern for progression to severe disease. Thrombocytopenia is common in both mild and severe infections.
- Symptoms of dengue hemorrhagic fever/severe dengue include all of the above *plus* a capillary leak syndrome causing shock and multiorgan system failure. This occurs in the 24 to 48 hours after fever resolution and reflects an immune dysregulation phenomenon. Counterintuitively, due to the capillary leak, hemoconcentration and rising hematocrit is typical. Frank hemorrhage is rare outside of preexisting peptic ulcer disease or the use of salicylates or ibuprofen, which may cause gastritis and alter platelet function.
- Diagnosis is made by clinical suspicion in most settings, serum PCR during the febrile phase, and serology during the convalescent phase. Serology may cross react with other flaviviruses, such as West Nile, Japanese encephalitis, and yellow fever (including recent vaccinations). A positive tourniquet test may be used to identify capillary fragility but may have low specificity based on the prevalence of other endemic diseases.
  - Inflate a blood-pressure cuff on the upper arm to a point midway between the systolic and diastolic pressures for 5 minutes.
  - A test is considered positive when 10 or more petechiae per 2.5 cm^2 (1 $in.^2$) are observed after the cuff pressure has been released for 2 minutes.
- Treatment of mild cases includes symptomatic care with acetaminophen and oral hydration.
- Managing severe disease consists of meticulously replacing isotonic fluids to provide for urine output of 1 to 2 cc/kg/h and a gradual reduction in hematocrit back to normal levels. Overusing IV fluids leads to iatrogenic morbidity and mortality. Platelet transfusion does not impact the disease course and is not indicated. In rare cases of severe hemorrhage,

red blood cell transfusions are indicated. The WHO publishes management algorithms.
- Prevention and control require avoiding bites. This can be accomplished by using repellants and destroying or larviciding breeding sites (eg, tires, trash, and water cisterns) for *Aedes aegypti*.

Chikungunya Virus

- Etiology/Epidemiology
  - Endemic to Africa, Southeast Asia, and the Indian and Pacific Oceans.
  - In late 2013, chikungunya virus was found for the first time in the Americas on islands in the Caribbean and has since become widespread in Central and South America, with more than 1.2 million suspected cases reported.
  - Vectors: *Aedes aegypti* and *Aedes albopictus* mosquitoes. These are the same daytime-biting mosquitoes that transmit dengue virus.
- Symptoms usually begin 3 to 7 days after being bitten by an infected mosquito.
  - The most common symptoms are fever and joint pain.
  - Other symptoms may include mild headache, muscle pain, arthritis of the small joints, and rash.
  - Although rarely fatal, the symptoms can be severe and disabling. Most patients feel better within a week. In some people, the joint pain may persist for months.
- Diagnosis is made by PCR and serology.
- Treatment is solely supportive.
- Control and prevention can be achieved by eradicating and larviciding breeding sites and by using personal repellants.
- Distinguishing chikungunya from dengue can be difficult because the symptoms are similar to those of dengue: arboviral disease with identical vectors and overlapping geographic range.
  - Severe manifestations are rare in cases of chikungunya.
  - Capillary leakage or bleeding diathesis points to dengue.
  - Chikungunya joint pain is classically in the small joints of the hands and may be frank arthritis, compared to the lumbosacral arthralgias and diffuse myalgias of dengue.

- When both are suspected, assume dengue. Chikungunya is rarely fatal. In contrast, early identification and proper clinical management for hospitalized dengue cases can reduce the case fatality rate of severe dengue disease from 10% to less than 0.1%.

Yellow Fever

- Epidemiology: Flavivirus transmitted to humans primarily through the bite of infected mosquitoes in certain South American and African countries. For list of countries, see the CDC webpage on yellow fever (http://www.cdc.gov/yellowfever/maps/index.html).
- Symptoms
  - The majority of those infected have no illness or only mild illness.
  - In persons who develop symptoms, the incubation period is typically 3 to 6 days.
  - The initial symptoms include sudden onset of fever, chills, severe headache, back pain, general body aches, nausea and vomiting, fatigue, and weakness. Most people improve after initial presentation.
  - After a brief remission of hours to a day, roughly 15% of cases progress to develop a more severe form of the disease, characterized by high fever, jaundice, bleeding, and eventually shock with failure of multiple organs.
    - In those who become symptomatic but recover, weakness and fatigue may last several months.
    - Among those who develop severe disease, 20% to 50% may die.
- Diagnosis
  - Serologies (many cross react with other flaviviruses, such as West Nile, Japanese encephalitis, and dengue).
  - PCR can be used if it is still early in the disease course. By the time jaundice or organ failure is detected, the PCR will be negative.
  - Similarly, viral culture can be used but will only test positive early in the disease course.
  - Immunohistochemical staining of specimens, such as those taken from lymph nodes or liver biopsy, may help in diagnosis.

- Treatment is supportive. Survivors have life-long immunity after recovery.
- Prevention
  - Control and prevent mosquitos.
  - Provide vaccine (live attenuated virus).
    - A single dose of vaccine protects against disease for 10 years or more.
    - Serious adverse events can occur following yellow fever vaccination. Therefore, persons should only be vaccinated if they are at risk of exposure to yellow fever virus or require proof of vaccination for country entry. Vaccination of immune-compromised individuals is contraindicated.
      - A medical waiver can be given to those with a precaution or contraindication to vaccination.
      - Vaccination requirements and recommendations for specific countries are available on the CDC Travelers' Health webpage (http://wwwnc.cdc.gov/travel).

Humanitarian Issues

Children make up a large portion of the people involved in refugee and displacement situations. Common illnesses, such as diarrheal and respiratory illnesses, may proliferate. The majority of respiratory tract infections will be viral in origin and do not require antibiotic therapy. Antibiotics should be used only for complicated URIs (otitis media or sinusitis with fever, or mastoiditis) and all suspected acute lower respiratory tract infections (eg, pneumonia).

Limited numbers of trained medical personnel cannot care for hundreds or thousands of refugees on an individual basis. It is the goal in these settings for medical personnel to give hands-on training to volunteers from within the refugee population. Volunteers should be trained in vitamin-A administration, preparation and delivery of WHO rehydration formulas, and vaccine administration to prevent disease within the camp. They should be given limited training in triage so they can determine who should actually receive care from medical professionals. Medical professionals should limit their care to those most in need of trained providers. Some treatment recommendations

may differ slightly in this chapter from other opinions in this text because in a refugee situation, resources are often extremely limited. In endemic areas consideration should be given to mass drug administration for soil-transmitted helminthes to treat and prevent iron deficiency (see Chapter 35, Emergency Nutrition, for details). See Chapter 43, Humanitarian Operations, for guidance on successfully planning and executing large-scale humanitarian missions.

Further Reading

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Chapter 30

Endocrinology

Introduction

This chapter provides a basic approach to endocrine issues in an austere or combat environment, emphasizing signs, symptoms, and an index of suspicion for serious, potentially life-threatening situations. Hormone dosing is best determined using accurate height and weight to allow exact calculation of body surface area.

$$\text{Surface area } (m^2) = \sqrt{\frac{\text{Ht (cm)} \times \text{Wt (kg)}}{3{,}600}}$$

When this information is not available, use the estimates obtained from a Broselow tape (see inside back cover).

Diabetes Mellitus

- Diabetes diagnostic criteria include:
  - fasting blood sugar greater than 126 mg/dL,
  - random blood sugar greater than 200 mg/dL in association with symptoms of diabetes, or
  - blood sugar greater than 200 mg/dL 2 hours after an oral glucose tolerance test.
- Symptoms of diabetes mellitus include polyuria, nocturia, polydipsia, and polyphagia.
- Weight loss will often occur with diabetes mellitus type 1 (DM1), but can occur with diabetes mellitus type 2 (DM2).
  - Children with polyuria, nocturia, polydipsia, and polyphagia who are not overweight should be suspected of having DM1 if their blood sugar is elevated.
  - Management of DM2 depends on the presentation at the time of diagnosis.

- Random blood sugar less than 200 mg/dL without marked elevations 1 to 2 hours after meals can often be managed by diet, exercise, and weight loss without the initiation of medications.
- Random blood sugar greater than 200 mg/dL will require medication.
  - Use caution when initiating antidiabetic medication regimens in austere environments with limited laboratory or clinical follow-up options.
  - Consider the risk of hypoglycemia.
  - For an overweight, newly diagnosed patient with DM2 with random blood sugar between 200 and 300 mg/dL, administer metformin 500 to 1,000 mg once or twice a day.
  - Insulin should be strongly considered in a hyperglycemic, nonacute patient with random blood sugar greater than 300 mg/dL, although oral therapy may be safer (see below).

Diabetic Ketoacidosis

- Diabetic ketoacidosis (DKA) is diagnosed when a patient has:
  - D: high glucose.
  - K: ketones in the blood.
  - A: acidosis.
- Perform a brief history and physical examination to assess for shock and degree of volume depletion (Table 30-1).
  - Physicians frequently overestimate the degree of fluid depletion.
  - The best data are the patient's actual weight loss (use outpatient records if available).
- Obtain results from the following laboratory tests:
  - chemistry panels, including calcium, magnesium, and phosphorous, if available;
  - arterial blood gas or venous blood gas analysis;
  - serum ketones test;
  - urinary analysis;
  - C-peptide test; and
  - consider looking for an infectious trigger via complete blood count with differential, urine culture, and the like.

Table 30-1. Assessing Dehydration in the Pediatric Patient with Diabetes

Parameter	Mild	Moderate	Severe
Estimated volume deficit (%)	3	6	10
Clinical signs			
Perfusion	Normal	Normal or ↓	↓
Heart rate	Normal	↑	↑
Blood pressure	Normal	Normal or ↓	Normal or ↓
Labs			
HCO_3	Normal	10–20	< 10
pH	Normal	> 7.20	< 7.20
Glucose	300–400	400–600	> 600
BUN	< 20	< 30	> 25

BUN: blood urea nitrogen
HCO_3: bicarbonate

- Obtain intravenous (IV) access and begin correcting deficit slowly, unless patient is in shock.
  - Give normal saline (NS) 10 to 20 mL/kg over 1 hour.
  - The rest of the deficit should be replaced over 48 hours to avoid dropping serum osmoles too quickly and precipitating cerebral edema.
  - Placing two large IVs allows treatment through one and sampling through the other.
- Insulin therapy need not be viewed as emergent therapy, but should be initiated as soon as possible.
  - Use regular insulin (100 units in 100 mL NS) with an insulin drip at 0.05 to 0.1 units/kg/h.
  - **Do not bolus with insulin**; it can precipitously drop glucose levels and serum osmolarity, exacerbating risk of cerebral edema.
  - The goal of therapy should be a drop in serum glucose of 50 to 100 mg/dL/h (start on the low end of the range and increase over time).
  - Plastic tubing binds insulin; run insulin through tubes before using.
  - Blood sugar checks should be done every hour.
  - In mild DKA, especially in the austere environment, if no IV access is available, intramuscular (IM) insulin can be given every 3 hours, rather than using an insulin drip.

    - The dose of IM regular insulin is 0.1 to 0.3 units/kg.
    - Start at the low end and increase over time to avoid inadvertently administering excessive amounts of insulin.
- Preferred fluid choice is ½NS with potassium.
    - Use potassium chloride and potassium phosphate to administer 40 mEq/L (even though the patient is hyperkalemic, total-body potassium is low).
    - Add glucose when blood sugar drops into the 250 to 300 mg/dL range.
    - Always anticipate the next bag needed and order it ahead of time from the pharmacy. Be prepared to escalate dextrose concentration from 5% to 10% or 12.5% dextrose to stabilize glucose levels while the insulin works to clear the acidosis.
- Cerebral edema is a major concern; perform neurological checks hourly.
    - When faced with a deteriorating mental status, consider performing a computed tomography scan of the head to look for cerebral edema.
    - Administer mannitol (dose 0.25 g/kg) for progressive neurological deterioration or focal neurological examination.
    - **There is a high risk for cerebral edema when fluids are administered at more than 4,000 mL/m^2/day.**
- Check glucose hourly, venous blood gas or arterial blood gas tests and chemistry panels every 4 hours, and urinary analysis every void (or more frequently when necessary).
- Do not reduce insulin prematurely if glucose is falling—give more glucose! Giving enough glucose ($D_5 > D_{10} > D_{12.5}$) allows room to provide enough insulin to correct the acidosis.
- Transition to subcutaneous (SQ) insulin from insulin drip when patient is expressing hunger, the acidosis is mostly gone, and there is food immediately available.
    - Turn off the drip, administer the SQ insulin, and wait 30 minutes before feeding.
    - Typically, rehydration without glucose will need to be continued once the patient is eating.

Diabetes Management

- Dietary management is generally the same in DM1 and DM2.
  - Dietary treatment of diabetes consists of a well-balanced diet low in refined and simple sugars.
  - The diet should be approximately 55% carbohydrate, 30% fat, and 15% protein.
  - Carbohydrate intake should favor complex carbohydrates.
    - In general, infants and toddlers (0–3 years old) will need 30 to 45 g of carbohydrates per meal.
    - Older children (4–12 years old) need 45 to 60 g of carbohydrates per meal.
    - Teenagers (13–18 years old) need 75 to 90 g of carbohydrates per meal.
- Insulin therapy
  - Insulin therapy and timing depends on the type of insulin available (Table 30-2).

Table 30–2. Types and Action Times of Insulin

Type of insulin	Onset	Peak (h)	Duration (h)
Lispro/aspart	10–15 min	1–2	2–4
Regular	30–60 min	2–4	6–9
NPH	1–2 h	3–8	12–15
Lente	1–2 h	3–14	18–20
Ultralente	2–4 h	6–14	18–20
Glargine	1–2 h	2–22	24

NPH: Neutral Protamine Hagedorn

    - In theater, it is likely that only neutral protamine Hagedorn (NPH) and regular insulin are available.
    - Start with a total daily dose of 0.6 units/kg/day if the initial glucose at diagnosis is less than 500 mg/dL.
      - When initial glucose at diagnosis is greater than 500 mg/dL and there is no acidosis, use a total daily dose of 0.8 units/kg/day.
      - When initial glucose at diagnosis is greater than 500 mg/dL and acidosis is present, use a total daily dose of 1.0 unit/kg/day.
      - When initial glucose at diagnosis is unavailable, start with 0.8 units/kg/day.

- Morning insulin should constitute two-thirds of the total daily dose.
  - This amount should be divided further to two-thirds NPH and one-third regular insulin (Exhibit 30-1).

Exhibit 30-1. Case Study: Insulin Dosing Using Neutral Protamine Hagedorn and Regular Insulin

A 30-kg patient presents with an initial blood glucose of 558 mg/dL and serum bicarbonate of 20 mEq/L.
Administer 0.8 units/kg/day × 30 (24 units/day).

Morning:
⅔ of the total dose = 16 units total (10 units NPH and 6 units of regular insulin before breakfast)

Evening:
The remaining ⅓ total dose = 8 units total (4 units of NPH and 4 units of regular insulin before dinner)

NPH: Neutral Protamine Hagedorn

  - This dose should be given about 20 minutes before breakfast.
- The evening dose should constitute one-third of the total daily dose.
  - This amount should further be divided into one-half NPH and one-half regular insulin.
- This dosing plan places a child at risk for low blood sugar; the child should have small snacks in the midmorning, midafternoon, and at bedtime when this insulin plan is used.

- Children on insulin should have multiple blood sugar checks per day.
- A combination of rapid-acting insulin (lispro or aspart) and glargine is preferable to the regular and NPH insulin combination, if available, because it more closely approximates normal physiology (further pediatric endocrinology consultation is recommended).
- In an austere environment, use a goal blood sugar of 150 mg/dL.

Hypoglycemia

- Signs and symptoms
  - Hypoglycemia is nonspecific in infancy, but can include cyanotic episodes, apnea, respiratory distress, refusal to feed, myoclonic jerks, convulsions, somnolence, hypothermia, sweating, and more.
  - For older children, symptoms include anxiety, weakness, hunger, shakiness, sweating, tachycardia, nausea, vomiting, headache, visual disturbances, lethargy/lassitude, restlessness, mental confusion, somnolence/stupor, convulsions, bizarre neurological signs, decreased intellectual ability, personality changes, and bizarre behaviors.
  - Other physical findings associated with recurrent hypoglycemia include hepatomegaly, short stature, large size for gestational age (newborn), and hemihypertrophy of an extremity.
- The definition of hypoglycemia is less than 40 mg/dL in the first month of life (older infants, children, and teenagers should be able to maintain a blood sugar greater than 60 mg/dL).
- The differential diagnosis includes a host of congenital metabolic and hormonal disorders, systemic disease, and drug intoxications; the presence of urine ketones may be helpful in diagnosis.
  - If urine ketones are positive, it is likely that a transient abnormality exists that can be treated with IV or oral glucose therapy.
  - The absence of ketones in the face of profound hypoglycemia generally represents an excess of insulin secretion or the presence of a disorder of fatty acid metabolism.
- Treatment varies by age.
  - Neonates: 2 to 4 mL/kg 10% dextrose in water ($D_{10}W$) IV bolus.
  - Children: 2 to 4 mL/kg 25% dextrose in water ($D_{25}W$) IV, administered slowly.
    - Follow each immediately by continuous glucose infusion.

        - If IV therapy is unavailable, oral or nasogastric therapy should be undertaken in a child that is awake and able to tolerate it.
    - If a child is actively seizing or comatose due to low blood sugar, administer 1 mg of glucagon IM. Be aware that vomiting is common after glucagon administration; lay children on their sides after giving glucagon.

Thyroid

- Hypothyroidism
    - Hypothyroidism can be congenital or acquired.
    - Congenital hypothyroidism is almost impossible to recognize early on. Signs and symptoms include:
        - macroglossia,
        - open posterior fontanelle,
        - developmental delay,
        - constipation, and
        - coarse facial features, including a broad nasal bridge, eyelid edema, flat facies, and a large head.
    - Treatment for congenital hypothyroidism is oral thyroid replacement.
        - Starting dose is 12 to 15 μg/kg/day for neonates.
        - Most children with congenital hypothyroidism are on 5 μg/kg/day of levothyroxine by 1 year of age.
        - Most infants require 37.5 μg daily (given as 1.5 25-μg tablets).
        - Pills should be crushed, mixed in formula or applesauce, and given directly to the patient. **DO NOT** make elixirs for this therapy (stability may be affected).
    - Acquired hypothyroidism is recognized by the presence of the following signs and symptoms:
        - constipation,
        - fatigue,
        - cold intolerance, and
        - enlarged thyroid gland.
    - Most children with acquired hypothyroidism require an initial dose of 2 to 3 μg/kg/day of levothyroxine.
- Hyperthyroidism

- Symptoms of hyperthyroidism in infants and children include:
  - irritability,
  - flushing,
  - tachycardia,
  - hypertension,
  - poor weight gain,
  - goiter,
  - exophthalmos, and
  - hepatosplenomegaly, jaundice, thrombocytopenia, and hypoprothrombinemia.
- Signs are typically subtle and slowly progressive. Initial signs of irritability and jitteriness should lead one to suspect sepsis or hypoglycemia first.
- Treatment in infants and children is initiated with propranolol (1 to 2 mg/kg/day divided three times daily [tid]) and propylthiouracil (PTU) 5 to 10 mg/kg/day divided tid.
- The female-to-male ratio of acquired hyperthyroidism in teenagers is 5 to 1.
- Symptoms in teenagers include:
  - tachycardia,
  - restlessness,
  - difficulty sleeping,
  - widened pulse pressure,
  - heat intolerance,
  - increased frequency of loose stools, and
  - enlarged, nontender thyroid.
- Etiology is generally autoimmune but if a prominent thyroid nodule is palpable, that may be the cause.
- Treatment in teenagers can be surgical resection of all or part of the thyroid gland, or medical or radioactive iodine ablation.
  - Medical treatment consists of β-blocker therapy with atenolol (25 to 50 mg/day) until the marked symptoms have resolved, and PTU at 5 to 10 mg/kg/day divided tid.

- If medical treatment is initiated, thyroid function tests should be obtained prior to therapy and sent to a referral laboratory (this should be possible in a deployment situation).
- After the free thyroxine level has normalized or lowered, add levothyroxine at 2 μg/kg/day to maintain a euthyroid state.
- The thyroid can be adequately suppressed while treating the patient with PTU.

Adrenal Disorders

- Adrenal insufficiency is uncommon; however, an index of suspicion for adrenal disorders is critical because they can be fatal.
- A patient with a known autoimmune condition, such as diabetes or thyroid disease, has the potential to develop adrenal insufficiency.
- Tuberculosis, human immunodeficiency virus, adrenal hemorrhage, and traumatic adrenal resection may also lead to adrenal insufficiency.
- Signs and symptoms include:
  - unexplained hypotensive shock;
  - progressive weakness, fatigue, dehydration, and hypotension (these are the most common symptoms);
  - anorexia, nausea, vomiting, myalgias, and personality changes (possible symptoms); and
  - other suggestive physical findings, such as hyperpigmentation of the skin and mucous membranes (especially the creases and the nipples); vitiligo and alopecia may also be associated.
  - Laboratory evidence suggestive of adrenal insufficiency includes hyponatremia, hyperkalemia, and hypoglycemia. Unexplained eosinophilia may also be present in the acutely ill patient.
- If adrenal insufficiency is suspected, obtain a blood specimen in a serum separator tube (red, tiger, yellow). Separate the serum and freeze the specimen.
- Treatment includes aggressive IV fluid therapy (20 cc/kg bolus of NS followed by reassessment).

- Pressor agents are sometimes required.
- Hydrocortisone hemisuccinate should be given urgently by IV (50 mg/m^2).
  - Infants: 25 mg.
  - Toddlers and young children (less than 6 years old): 50 mg.
  - Older children and teenagers (6 and older): 100 mg.
- Regular dosing (every 6 hours) should be continued at a dose of 100 mg/m^2/day, divided in equal doses.
- If the adrenals have been removed or primary adrenal disorders are suspected, mineralocorticoid therapy (fludrocortisone) will be necessary when the hydrocortisone dose is dropped below 100 mg/m^2/day.
  - This is safe when the child stabilizes or the significant stressor (surgery, illness, etc) has resolved.
  - Maintenance hydrocortisone dose is 12 to 15 mg/m^2/day (divided tid).
  - Fludrocortisone dose is 0.1 mg twice daily for infants, and 0.1 mg four times daily in patients 1 year and older.

Calcium and Vitamin D Disorders

- Hypocalcemia
  - Symptoms can range from nothing to severe (eg, tetany and seizures).
  - Long QT interval is apparent on electrocardiogram.
  - Symptomatic hypocalcemia generally occurs when calcium levels in the blood are below 6 mg/dL.
  - Managing acute hypocalcemia requires calcium and vitamin D.
    - Administer 10% calcium gluconate at 1 mL/min, not to exceed 2 mL/kg.
    - Give IV but with care; SQ infiltration of calcium can cause severe burns.
    - Vitamin D is given as calcitriol at a dose of 20 to 60 ng/kg/day.
    - Once acute symptoms have resolved, oral calcium should be given at 50 to 75 mg of elemental calcium per kilogram of body weight every 24 hours (oral calcium is much safer to give than IV calcium).

        - Vitamin D may be needed long term in some cases, such as in the presence of hypoparathyroidism.
        - Hypocalcemia may not respond to therapy if the patient's magnesium level is also low (see Hypomagnesemia, below).
- Hypercalcemia
    - Severe hypercalcemia (more than 13.5 mg/dL) requires treatment.
    - Initiate treatment with IV NS to establish optimal fluid hydration.
        - Once urine output is substantial (more than 2 cc/kg/h), give furosemide at a dose of 1 to 2 mg/kg IV.
        - If hypercalcemia persists, give hydrocortisone hemisuccinate 1 mg/kg IV every 6 hours.
        - Bisphosphonates can also be used, but are not likely to be available in an austere environment.
        - In an immobilized patient, it may be prudent to start a low-calcium diet and avoid vitamin D.
        - Encourage copious fluid intake.
- Hypomagnesemia
    - Hypomagnesemia may cause hypocalcemia.
    - Hypocalcemia will be resistant to treatment in the presence of untreated hypomagnesemia.
    - Treat magnesium levels below 1.4 mg/dL.
    - Treatment consists of 50% magnesium sulfate 0.1 to 0.2 mL/kg. Repeat the dose in 12 to 24 hours if the magnesium level remains low.
- Rickets
    - The most common cause of rickets is vitamin D deficiency.
    - Infants and children at risk for vitamin D deficiency typically have a history of prolonged breast-feeding and live in a northern latitude.
    - Signs and symptoms of rickets include:
        - rachitic rosary,
        - bowed legs,
        - bowing forearms,
        - frontal bossing,
        - craniotabes,
        - short stature,

- suboptimal weight, and
- systemic symptoms, including hypotonia, weakness, anorexia, and delay in walking.
- Vitamin D deficiency can present as seizures when severe hypocalcemia is present.

- Radiographic evidence of vitamin D deficiency consists of cupping, widening, and irregularity of the distal metaphyses; there is also evidence of osteopenia with cortical thinning.
- Treatment in an urgent situation includes administering IV calcium and providing vitamin D treatment.
  - In an otherwise normal child, ergocalciferol should be administered in doses of 1,000 to 2,000 international units (IUs) per day. Start at the higher end of the dose and wean to 1,000 IU/day after 2 to 4 weeks.
  - Supplemental vitamin D should be continued until there is radiographic evidence of healing. This usually takes 2 to 3 months, but can take longer in cases of severe vitamin deficiency.
  - If symptoms of vitamin D deficiency persist despite adequate replacement, changing vitamin D to 1,25-hydroxyvitamin D may alleviate the problem.
    - Calcitriol should be used at a dose of 20 to 60 ng/kg/day.
    - Calcitrol has a long half-life and care should be taken not to overdose the medication. Monitor for hypercalcemia.
- To prevent rickets, breast-fed babies should receive a daily multivitamin containing 400 IU of vitamin D.

Chapter 31

Common Neurological Problems

Pediatric Neurological Examination

Neurological examinations help identify abnormalities in a structured manner. Key elements assessed include development (see Developmental Stages in Chapter 36, Nursing Assessment), cognition, motor, and sensory processing. Identifying neurological defects helps localize the area affected (brain, spine, nerve, muscle, multiple areas of nervous system) and aids in the subsequent development of a differential diagnosis.

Key Aspects of a Pediatric a Neurological Examination

The mental status aspect of a pediatric neurological exam differs from that in adults and is discussed in greater detail later on in this chapter.

- The following are common to both pediatric and adult neurological exams:
  - age-appropriate awareness of current environment, and
  - ability to communicate.
- Cranial nerves are assessed, including:
  - Motor nerves.
    - Muscle bulk
      - Increased muscle bulk is evidence of hypertrophy (compensated overuse), or pseudohypertrophy (Duchenne muscular dystrophy, storage disease).
      - Decreased muscle bulk is evidence of a central nervous system process (stroke, cortical malformation, spinal cord injury) or a peripheral nervous system process (neuropathy, myopathy).
    - Muscle tone is the inherent resistance of musculature at rest.

        - Increased tone suggests central nervous system pathology (upper motor neuron finding) involving the brain or spinal cord.
        - Decreased tone is seen in infants and toddlers under age 2 with processes involving the brain. It often transitions to increased tone as the child ages (for example, in the case of spastic quadriplegia from perinatal anoxia). Low tone in older children suggests peripheral nervous system pathology (lower motor neuron finding) involving nerves or muscle.
    - Muscle strength is one's ability to move extremities against resistance.
    - Reflexes: increased reflexes suggest central nervous system pathology (upper motor neuron finding). Decreased reflexes suggest peripheral nervous system pathology (lower motor neuron finding; eg, absent reflexes in spinal muscular atrophy).
    - Primitive reflexes come and go over time. For example, Babinski reflex is present until age 12 months; Moro reflex is present from birth to age 6 months; anterior propping is present at 4 to 5 months; parachute reflex is present at 6 to 12 months; and lateral propping is present at 6 to 7 months.
- The sensory system is the most difficult aspect of the exam to assess objectively and it is difficult for a young child to cooperate with it.
- Gait should be assessed to determine if it is appropriate for the child's age (most children walk independently by age 18 months). Observe for ataxia, pain, and abnormal posture in limbs.

Altered Mental Status

The following are important to consider in children when performing a pediatric neurological examination.

- Was the child age appropriate in development prior to evaluation? This includes development in the following areas:
    - gross motor functions,
    - fine motor functions,

    - language, and
    - social interactions.
- Timing of the change.
    - Acute (encephalopathy and encephalitis)
        - trauma (head injury, occult hemorrhage),
        - infection (bacterial, viral, parasitic),
        - rapidly progressive intracranial pressure (ICP; hydrocephalus, intracranial hemorrhage),
        - ingestion (alcohol, medications, toxins around home),
        - toxic/metabolic (carbon monoxide, heavy metals, electrolyte abnormalities, glucose),
        - autoimmune (acute disseminated encephalomyelitis, multiple sclerosis, cerebritis),
        - psychiatric (mood disorder, primary psychosis), and
        - epilepsy (focal, generalized).
    - Subacute/chronic (regression, static encephalopathy)
        - congenital/cerebral palsy (hypoxemia at birth),
        - hydrocephalus,
        - slow-growing mass lesion (tumor, parasite, abscess),
        - endocrine (thyroid, glucose),
        - metabolic disorders (mitochondrial disorders and inborn errors of metabolism), and
        - chromosomal abnormalities (trisomy, fragile X, etc).

Attempt to rapidly diagnose and correct reversible causes, especially of acute mental status changes.

Weakness

- The child's age and timing of the onset of weakness assist with determining the most likely etiology of weakness.
    - Infants
        - Chronic: hypoxic ischemic encephalopathy, congenital cerebral malformations, and perinatal stroke.
        - Subacute and progressive: hydrocephalus, spinal muscular atrophy, muscle disorder, chromosomal.
        - Acute: sepsis, meningitis, spine trauma, metabolic derangement, botulism, organophosphate exposure, and tick paralysis.
    - Children

- Chronic: cerebral palsy, cerebral malformations, and perinatal stroke.
- Subacute: cerebral or spinal mass, muscle disorder, and spinal muscular atrophy.
- Acute: Guillain-Barré syndrome, spine trauma, acute stroke, organophosphate exposure, tick paralysis, focal seizure, and polio.

Hypotonia

The causes of hypotonia are myriad and the sources can be from the brain (eg, severe prematurity), spinal cord (eg, meningomyelocele), anterior horn cell (eg, spinal muscular atrophy), neuromuscular junction (eg, botulism), peripheral nerve (eg, Guillain-Barré), muscle (eg, Duchenne muscular dystrophy), or the ligaments (eg, Marfan syndrome). Seek expert consultation or a pediatric neurology text for more comprehensive diagnosis, diagnostics, and management advice.

Headache

- The following red flags associated with headaches warrant increased attention and additional work-up (neuroimaging, laboratory tests, lumbar puncture):
  - patient describes pain as the worst headache of his/her life (subarachnoid hemorrhage);
  - progressive symptoms (mass lesion, hydrocephalus);
  - fever (meningitis, encephalitis, abscess);
  - persistent visual change, diplopia (increased ICP);
  - focal weakness or sensory change on examination (mass lesion, hemorrhage);
  - depressed mental status;
  - headache always in the same location; and
  - asymmetric pupils.
- If red flags are present, consider additional medical evaluations, including:
  - admission to a medical facility for close clinical monitoring,
  - frequent neurologic checks,
  - vital signs monitoring, and
  - "STAT" head imaging (computed tomography or magnetic resonance imaging).

- Consider lumbar puncture *after* neuroimaging and if there are no concerns for elevated ICP.

- Headache is a common complaint in all children as they age (more reported in adolescents).
- Frequent primary headache types:
  - Migraine (75% of all pediatric headaches)
    - Migraine consists of four phases: prodrome, aura (if present), headache, recovery.
    - Associated symptoms include photophobia, phonophobia, nausea, emesis, and desire to sleep.
    - Common auras include bright flashes, lines, colorful spheres, and objects in vision appearing large or small.
    - Headaches may be unilateral, bifrontal, or bitemporal, or may occur in the posterior scalp/neck region.
    - Duration is minutes up to several days.
    - Triggers are numerous and include stress, anxiety, foods, lack of sleep, dehydration, etc.
    - Patient may also have family history of frequent migraines in immediate family.
  - Acute symptomatic medications best early in headache include:
    - Nonsteroidal antiinflammatory drugs (NSAIDs) or acetaminophen as first-line treatments.
      - Ibuprofen (10 mg/kg every 6–8 hours, oral, maximum dose of 1,200 mg/day).
      - Naproxen (5 mg/kg every 10–12 hours oral, maximum daily dose 600 mg/day).
      - Acetaminophen (15 mg/kg every 4–6 hours oral).
      - Ketorolac (0.5 mg/kg intravenous [IV] or 1 mg/kg intramuscular [IM] daily, maximum IV dose 15 mg, maximum IM dose 30 mg).
      - Triptans (older children):
        - rizatriptan (5 mg for children under 40 kg; 10 mg for children 40 kg and larger as a single oral dose).
        - sumatriptan (5–20 mg intranasal in those older than 5 years, **as a single dose**, given as soon as possible after the onset of migraine).
  - Tension headache
    - Typically bifrontal and band-like pain.
    - Typically no aura.

- Duration is minutes to days.
- Similar triggers as migraines.
- Give NSAIDs or acetaminophen as first-line treatments (see above).

- Cluster headaches
  - Rare in children under 10 years old.
  - Severe unilateral pain located in frontal and orbital regions.
  - Duration is minutes to 3 hours.
  - Associated with ipsilateral lacrimation, rhinorrhea, ophthalmic injection, and occasionally Horner's syndrome.
  - Acute symptomatic medications include 100% oxygen and triptans (see above).
  - Prophylaxis:
    - verapamil (4–8 mg/kg/day divided three times daily), OR
    - topiramate (2–3 mg/kg/day divided twice daily. Do not abruptly discontinue therapy; taper dosage gradually to prevent rebound effects).
- Chronic daily headache
  - Headache frequency is 15 or more days a month for longer than 3 months in the absence of organic pathology.
  - Often associated with medication overuse; child should not use acute treatments more than three times per week.
  - Treatment options:
    - family education;
    - reduction in use of acute headache medications;
    - cyproheptadine (age over 3 years: 2–8 mg divided twice daily, maximum dose 0.5 mg/kg/day);
    - topiramate (age over 5 years: 2–3 mg/kg divided twice daily);
    - nortriptyline (age over 6 years: 0.5–1 mg/kg nightly);

OR

    - amitriptyline (age over 5 years: 0.25–1 mg/kg nightly).

Seizure

- Consider any seizure lasting longer than 5 minutes or more than 3 seizures in an hour as status epilepticus (see Chapter 8, Status Epilepticus).
- Typical clinical classifications include: febrile seizures, childhood epilepsy (focal or generalized), and provoked seizure (including posttraumatic seizure).

Febrile Seizures

- Febrile seizures occur when the child:
  - is normal in growth and development,
  - exhibits a convulsion associated with an elevated temperature greater than 38°C,
  - is 6 months to 6 years of age,
  - previously exhibited normal growth and development,
  - does not have central nervous system infection or inflammation,
  - does not have an acute systemic metabolic abnormality that may produce convulsions,
  - does not have a history of previous afebrile seizures, and
  - often has a family history of febrile seizures.
- Simple febrile seizures are the most common type of febrile seizure. They:
  - last less than 15 minutes,
  - have no focal features, and
  - occur once in a 24-hour period.
- Complex febrile seizures are seizures that:
  - last more than 15 minutes,
  - have focal features,
  - have postictal paresis, or
  - occur more than once in 24 hours.
  - No prophylaxis treatment is recommended.
  - There is a slightly elevated risk of epilepsy in complex febrile seizures.
  - Consider acute benzodiazepine for seizures longer than 10 minutes (see Chapter 8, Status Epilepticus).

Childhood Epilepsy

- Defined when any one of the following are present:
  - At least two unprovoked (or reflex) seizures occurring more than 24 hours apart.
  - Diagnosis of an epilepsy syndrome.
- Consider baseline metabolic screening, electroencephalogram, and neuroimaging (magnetic resonance imaging is better than computed tomography), if available.
- Evaluate for toxic metabolic states, infections, cerebral abnormalities (congenital injury, congenital malformations, remote perinatal stroke, mass lesions, etc).

Focal Epilepsy

- Focal epilepsy is the most frequent type of seizure after febrile seizure.
- Seizures originate from one cerebral hemisphere.
- Frequently associated with impaired consciousness.
- Motor seizures are characterized by:
  - focal motor activity,
  - anatomic spread or march of activity (Jacksonian),
  - versive movement (turning of the eyes, head, and/or trunk), and
  - vocalization or arrest of speech.
- Sensory seizures are characterized by:
  - paresthesias,
  - feelings of distortion of an extremity,
  - vertigo,
  - gustatory sensation,
  - olfactory symptoms,
  - auditory symptoms, and
  - visual phenomena, such as flashing lights.
- Autonomic seizures are characterized by:
  - epigastric "rising" sensation (a common aura with medial temporal lobe epilepsy),
  - sweating,
  - piloerection, and
  - pupillary changes.
- Auras with focal seizures include:

- psychic symptoms,
- dysphasia,
- feelings of familiarity ("deja vu"),
- distortions of time,
- affective changes (particularly fear),
- illusions, and
- formed hallucinations.
- Focal seizures may evolve to bilateral, convulsive seizures (secondary generalization).

Generalized Epilepsy

- Generalized epilepsy originates at some point within, and rapidly engages, bilaterally distributed networks.
- Consciousness is impaired.
- Motor manifestations are bilateral.
- Provoked seizures are secondary to another medical process, such as:
  - head trauma,
  - infection (meningitis, encephalitis, sepsis),
  - metabolic derangement (glucose, electrolytes), or
  - cerebral injury (stroke, intracranial hemorrhage).
- Treatment should focus on correcting the primary cause of cerebral injury or dysfunction. Consider immediate use of antiseizure medications in the setting of acute severe traumatic brain injury (reduce ICP and cerebral metabolic demand; see Chapter 8, Status Epilepticus, for treatment recommendations).

Antiepileptic Medications (Chronic Therapy)

The following medications are in order of preferred usage based on expert opinion. Consider neurology consultation prior to embarking on a chronic antiepileptic regimen.

Broad Spectrum (useful for focal and generalized seizures)

- Levetiracetam
  - Very good initial choice from safety and drug-to-drug interaction perspective.
  - Useful in newborns to adults.
  - Treats myoclonic seizures.

    - IV loading dose: 20 mg/kg.
    - Oral dosing: 20 to 60 mg/kg/day divided twice daily. Start with 10 mg/kg divided twice daily and increase by 10 mg/kg weekly.
        - Precautions: renal clearance; limit in cases of kidney failure.
        - May cause neuropsychiatric changes, agitation, and depression.
        - Few drug-to-drug interactions.
- Valproate
    - Not recommended for use in patients under age 2 because of a high risk of severe hepatotoxicity.
    - Treats myoclonic seizures well.
    - IV loading dose: 20 mg/kg.
    - Oral dosing: 20 to 60 mg/kg divided twice daily. Start with 10 mg/kg divided twice daily and increase by 10 mg/kg weekly.
    - Precautions: hepatotoxicity, life-threatening pancreatitis, thrombocytopenia, hyperammonemic encephalopathy, congenital malformations.
    - Liver metabolized, with some drug-to-drug interactions.
- Topiramate
    - Useful in newborns to adults.
    - There is no IV formulation.
    - Oral dosing: 5 to 10 mg/kg divided twice daily. Start with 3 mg/kg divided twice daily. Increase by 3 mg/kg weekly.
    - Precautions: cognitive impairment, appetite suppression, secondary acute angle closure glaucoma, acute myopia, metabolic acidosis, oligohydrosis, and nephrolithiasis.
- Phenobarbital (barbiturate)
    - Useful in newborns to adults.
    - IV loading dose: 15 to 20 mg/kg.
    - Oral: 5 mg/kg/day divided twice daily, maximum dose of 400 mg/day. Start 1 to 3 mg/kg divided once or twice daily. Increase by 1 mg/kg weekly.
    - Precautions: respiratory depression, depressed mental status, bradycardia.
    - Liver metabolized, with some drug-to-drug interactions.

- Clonazepam (benzodiazepine)
  - Useful from newborns to adults.
  - There is no IV formulation.
  - Oral dosing: 0.05 to 0.2 mg/kg/day divided two to three times daily, maximum dose of 20 mg/day. Initial dosing is 0.01 to 0.03 mg/kg/day given in 2 to 3 divided doses. Increase the dosage by no more than 0.25 to 0.5 mg daily, every third day, until seizures are controlled or maintenance dose of 0.1 to 0.2 mg/kg divided into 3 equal doses has been reached.
  - Precautions: respiratory depression, depressed mental status.
  - Liver metabolized with some drug-to-drug interactions.

Focal Seizure Medications (will worsen generalized epilepsy)

- Carbamazepine (shake liquid well before use)
  - Useful in patients aged 6 years to adult.
  - There is no IV formulation.
  - Oral dosing: 20 to 40 mg/kg divided twice daily. Start 10 to 20 mg/kg divided twice daily. Increase by 5 to 10 mg/kg weekly.
  - Precautions: depressed mental status, hyponatremia, angioedema, hypersensitivity reaction, and hepatotoxicity.
  - Liver metabolized, with some drug-to-drug interactions.
- Phenytoin (shake liquid well before use)
  - Useful in newborns to adults.
  - IV loading dose: 15 to 20 mg/kg.
  - Oral dosing: 5 to 10 mg/kg divided twice daily. Start 5 mg/kg divided twice daily. Increase by 1 mg/kg weekly.
  - Precautions: cardiac arrhythmias and arrest (infuse IV slowly at 1 mg/minute and dilute in normal saline), hypersensitivity reaction, depressed mental status, hepatotoxicity, hematologic toxicity, gingival hyperplasia, and coarsened facial features.
  - Phenytoin serum level determinations may be necessary for optimal dosage adjustments.
  - Liver metabolized, with some drug-to-drug interactions.

Table 31-1. TBI Severity Classification

	Mild	Moderate*	Severe*
Loss of consciousness	None or < 30 minutes	> 30 minutes to < 24 hours	> 24 hours
Altered consciousness	< 24 hours	> 24 hours	> 24 hours
Posttraumatic amnesia	< 1 day	> 1 day < 7 days	> 7 days
Glasgow Coma Scale	13–15	9–12	< 9

*Consider urgent medical evaluation at a tertiary care facility for moderate and severe traumatic brain injury.
TBI: traumatic brain injury

Concussion

Mild traumatic brain injury (TBI), also known as concussion, is a very common childhood injury and typically does not require hospitalization (Table 31-1).

- Immediately remove the patient from "high-risk" activities to avoid second impact syndrome (catastrophic cerebral edema and herniation).
- Expect full recovery (symptoms peak at 72–96 hours).
- Common causes of concussion include falls, assaults, play, sports, and motor vehicle accidents.
- Symptoms after concussion include:
  - headaches (consider further evaluation if red flags are present),
  - poor sleep,
  - irritability,
  - poor concentration, and
  - depressed mood.
- Gradually return to normal activities once symptoms have resolved.
- Recovery is often slowed when the patient sustains multiple concussions in 1 year.

- Consider neuroimaging if the following red flags develop: headache, new focal deficits, worsening cognition, and atypical recovery.

Posttraumatic Seizures

- Posttraumatic seizures require treatment in the acute setting, especially in the presence of increased ICP.
  - Phenobarbital is the preferred antiepileptic agent in patients less than 2 years old.
  - Treat older children with phenytoin sodium or fosphenytoin (see Chapter 13, Neurosurgery).
- Seizures within the first week of trauma need to be treated acutely; however, there is a low risk of long-term epilepsy.
- Patients who develop seizures after the first week following trauma are more likely to have posttraumatic epilepsy.

Further Reading

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Chapter 32

Hematology and Oncology

When blood disorders are being considered in a differential diagnosis, a detailed history, careful physical examination, and review of a blood smear can often yield an accurate diagnosis, even in the absence of advanced testing.

Anemia

- Anemia is a quantitative deficiency of hemoglobin (Hgb) or red blood cells less than a fifth percentile for age, with potential decreases in oxygen-carrying capacity.
- It can be due to decreased production, increased destruction, or increased losses.
- It is important to identify anemia as a sign or etiology of disease state.
- Understanding age-related normative values is imperative. Norms are readily available in resources such as *The Harriet Lane Handbook* (see Further Reading) or as shown in Table 32-1.

When to Suspect Anemia (Chief Complaints)

- Common symptoms of anemia include:
  - fatigue (classic symptom),
  - shortness of breath,
  - dizziness,
  - poor weight gain and failure to thrive,
  - complaints of chronic diarrhea, and
  - developmental delays.
- Anemia is more common in regions lacking in fortified foods (iron, B12, folate).

History

- Considerations include age, nutritional status, family history, medication history, and potential toxin exposure.

Table 32-1. Normal Red Blood Cell Values

Age	HgB (g/dL) Mean (–2SD*)	RBC Count ($\times 10^{12}$/L)	MCV (fL)	MCHC (g/%RBC)
0 days	16.5 (13.5)	3.9–5.5	108 (98)	33 (30)
1–3 days	18.5 (14.5)	4.0–6.6	108 (95)	33 (29)
2 wk	16.6 (13.4)	3.6–6.2	105 (88)	31.4 (28.1)
1 mo	13.9 (10.7)	3.0–5.4	101 (91)	31.8 (28.1)
6–8 wk	11.2 (9.4)	2.7–4.9	95 (84)	31.8 (28.3)
3–6 mo	12.6 (11.1)	3.1–4.5	76 (68)	35 (32.7)
6–24 mo	12.0 (10.5)	3.7–5.3	78 (70)	33 (30)
2–6 y	12.5 (11.5)	3.9–5.3	81 (75)	34 (31)
6–12 y	13.5 (11.5)	4.0–5.2	86 (77)	34 (31)
12–18 y				
female	14 (12)	4.1–5.1	90 (78)	34 (31)
male	14.5 (13)	4.5–5.3	88 (78)	34 (31)
18–49 y				
female	14 (12)	4.1–5.1	90 (80)	34 (31)
male	15.5 (13.5)	4.5–5.3	90 (80)	34 (31)

*2SD below mean.
HgB: hemoglobin
MCV: mean corpuscular volume
MCHC: mean corpuscular hemoglobin concentration
RBC: red blood cell
SD: standard deviation
Data source: Nathan DG, Oski FA. *Nathan and Oski's Hematology of Infancy and Childhood*. 6th ed. Philadelphia, PA: WB Saunders; 2003: 1841, App 11.

- In the newborn period (birth through 1 month), consider:
  - inheritable disorders of red blood cell production, such as hemoglobinopathies (eg, sickle cell) and thalassemias;
  - increased destruction, including enzymopathies, membranopathies, and neonatal alloimmunization;
  - prematurity (should also raise concerns of decreased nutritional stores); and
  - concomitant anomalies (may trigger concerns of a genetic disorder or prenatal infection).
- In older children, consider decreased production resulting from:

- nutritional deficiencies due to dietary insufficiency or intestinal malabsorption,
- poor utilization of nutrients in chronic inflammatory states,
- chronic occult blood loss,
- bone marrow failure syndromes,
- acquired aplastic anemias,
- medication-induced anemias, and
- organ dysfunction, such as chronic renal insufficiency, hypersplenism, portal hypertension (as seen in hepatic failure), and thyroid dysfunction.

Physical Examination

- Visually inspect the patient's palms, nail beds, conjunctiva, lips, and below the tongue for evidence of pallor. Pallor is a late sign of anemia and often reflects very low red blood cell counts.
- Scleral icterus or cola-colored urine will suggest increased destruction of red blood cells.
- Dysmorphic physical features may suggest a genetic condition or inheritable bone marrow failure syndrome.
- Check for tachycardia in a euvolemic state (see Chapter 1, Basic Approach to Pediatric Trauma, Table 1-1, for age-related normative values).
- In cases of severe anemia, a bounding precordium or rales in the lungs can indicate potential cardiac failure.
- Isolated splenomegaly suggests increased destruction or peripheral sequestration of blood, or occasionally, extramedullary hematopoiesis due to bone marrow failure.
- Murphy's sign reflecting the presence of cholelithiasis suggests increased destruction and turnover of blood cells, resulting in heme-pigmented stones and indirectly suggesting anemia.
- Isolated hepatomegaly associated with anemia can suggest a viral etiology.
- Hepatosplenomegaly associated with anemia can also suggest viral etiology or could represent malignancy.
- Easy bruising or bleeding should be noted; when it occurs with symptoms of anemia, consider a bone marrow process affecting multiple cell lines (leukemia), although viral infection is still possible.

- Observe the skin for dry or thinning hair, which suggests vitamin or hormone deficiencies such as hypothyroidism that may affect red blood cell production.
- Occult blood in the stool suggests chronic intestinal blood loss.
- Frontal bossing and maxillary hyperplasia can be signs of thalassemias.

Laboratory Evaluation

- Begin with a complete blood count (CBC) with reticulocyte count (RC) and peripheral blood smear evaluation. Normal peripheral red blood cell values generated by automated laboratory analyzers will vary by age.
- Although Hgb values are used to identify anemia, the additional information provided can help identify a process of inadequate production or increased destruction.
- Quick tools (applicable to children older than 1 year):
  - Microcytosis: mean corpuscular volume (MCV) is less than 70 + (age in years, up to age 10).
  - Macrocytosis: MCV greater than 100.
  - Hypochromia: greater than one-third diameter central pallor under microscopy, or low mean corpuscular Hgb concentration.
  - Hyperchromia: less than one-third diameter central pallor under microscopy, or high mean corpuscular Hgb concentration.
- Other parameters
  - RC: typically 1% to 3%.
    - Anemia with high RC indicates increased loss or destruction.
    - Anemia with low RC indicates decreased production.
  - Red blood cell distribution width (RDW): increased value suggests various sizes and shapes (decreased uniformity).

Diagnosis and Treatment: Microcytic Anemias

Iron Deficiency

- Additional symptoms of iron deficiency include pica and lack of concentration.

- Laboratory findings
  - Hypochromic, microcytic anemia.
  - Low RC.
  - High RDW.
  - Iron studies show low serum iron with high total iron binding capacity and low ferritin.
- Treatment depends on the level of symptoms.
  - Asymptomatic: 4 to 6 mg elemental iron per kilogram divided twice or three times daily. Increased reticulocytosis will be seen within 3 to 7 days.
  - If the patient is symptomatic, transfusion may be indicated. If intravenous (IV) iron is available, it may be considered for patients who do not tolerate oral iron, do not absorb oral iron, or in whom compliance may be a concern. A test dose given 1 hour before the first full infusion can screen for allergic reactions. Several formulations are available, with low molecular weight, iron dextran, and iron sucrose being the least likely to cause an allergic reaction or anaphylaxis.

Total iron deficit (mg) = body weight (kg) × (target Hgb – actual Hgb) (g/dL) × 2.4 + 500 mg (for patients over 35 kg).

Chronic Lead Poisoning

- Additional symptoms of chronic lead poisoning include abdominal pain, headaches, neurologic effects, constipation, failure to attain or regression of developmental milestones, growth arrest, and kidney disease.
- Physical examination will show gingival lead lines.
- Laboratory findings
  - Hypochromic, microcytic anemia.
  - Basophilic stippling in the RBC seen under microscopy.
  - Low RC.
  - Elevated lead level.
- Treatment
  - Remove exposure.
  - Levels above 45 μg/dL require chelation with dimercaptosuccinic acid or succimer; oral dimercaptosuccinic acid can be given at 30 mg/kg/day for 5 days, followed by 10 to 20 mg/kg/day for 14 days to prevent rebound in blood lead levels.

Thalassemia

- Thalassemia is an inherited disorder of Hgb synthesis with disordered production and hemolytic anemia.
- Can be α-thalassemia or β-thalassemia and is classified as minor, intermedia, or major based on symptoms and inheritance patterns.
- Regional patterns can often be determined in those with familial descent from the Mediterranean, North Africa, Middle East, India, Central Asia, and Southeast Asia.
- Symptoms
  - Failure to thrive, developmental delays, fatigue.
  - Present within first 2 years of life for thalassemia major, may be more indolent in intermedia; generally asymptomatic in thalassemia minor or trait.
- Physical examination will show scleral icterus, splenomegaly, and bony dysplasia (maxillary hyperplasia, vertebral expansion).
- Laboratory findings
  - Hypochromic, microcytic anemia.
  - Target cells.
  - Normal RDW.
  - High RC.
  - Quick tool: Mentzer index = MCV/RBC count
    - A result less than 12 is consistent with thalassemia.
    - A result greater than 13.5 is consistent with iron deficiency.
    - Although Hgb electrophoresis is not likely to be available
      - An elevated Hgb A2 would suggest beta thalassemia (trait or thalassemia major).
      - Alpha thalassemia intermediate (Hgb H disease) would have Hgb H.
      - Alpha thalassemia trait would have normal electrophoresis.
- Treatment depends on severity.
  - Thalassemia minor: no treatment (genetic counseling for future offspring).
  - Thalassemia intermedia: supplement with folic acid (1 mg orally daily) and provide supportive care for crises.

- Thalassemia major is diagnosed with Hgb, MCV, and Hgb electrophoresis. Give chronic blood transfusions and iron chelation; splenectomy is occasionally needed. **Note**: Iron deficiency and thalassemia may be concomitant, but thalassemias tend to have increased iron absorption; do not treat with iron unless the patient is deficient.

Chronic Inflammation

- Chronic inflammation prevents normal utilization of iron for Hgb synthesis.
- Signs and symptoms are consistent with the underlying disease.
- Laboratory findings
  - Hypochromic, microcytic, or normocytic anemia.
  - Low RC.
  - RDW is generally increased.
  - Iron studies show low serum iron and total iron binding capacity, as well as high ferritin.
- Treat the underlying disease.

Diagnosis and Treatment: Macrocytic Anemias

Vitamin B12 Deficiency

- Etiology: nutritional deficiency, poor intestinal absorption, parasites, or bacterial overgrowth.
- Symptoms include fatigue, pallor, and peripheral neuropathies. In infants, symptoms include tremors, microcephaly, developmental regression, and failure to thrive.
- Laboratory findings
  - Low RC.
  - Elevated RDW.
  - Neutropenia and thrombocytopenia may be present.
  - Microscopy may show hypersegmented neutrophils (6 or more lobes).
  - Serum B12 levels may be low.
    - Vitamin B12 deficiency is more common and occurs at younger ages in patients of northern European decent. It is rare in patients of Asian and African descent.

    - Additional laboratory abnormalities suggesting B12 deficiency include elevated lactate dehydrogenase, bilirubin, iron with increased transferrin saturation, and serum cholesterol; immunoglobulins may be decreased.
    - Bowel resections removing the ileum can result in B12 deficiency.
- Treatment
    - Consider other potential nutritional deficiencies.
    - For cases of inadequate intake, supplement with vitamin B12. Provide parenteral supplementation (intramuscular or subcutaneous; 1 mg weekly for 8 weeks and then monthly, or oral 1 mg daily). Reversal of neurologic symptoms can be seen in 48 hours.

Folic Acid Deficiency

- Etiology: nutritional deficit (drinking primarily goat's milk), poor intestinal absorption (celiac disease), increased body requirements (rapid growth or cell turnover), metabolic disorders (inborn errors of metabolism), or folate antagonistic drugs (eg, phenytoin, methotrexate, triamterene, trimethoprim) can result in folic acid deficiency.
- Symptoms include typical anemia symptoms without the associated neurologic symptoms seen in B12 deficiency.
- Laboratory findings are similar to those for vitamin B12 deficiency.
    - Low RC.
    - Neutropenia and thrombocytopenia may be present.
    - RDW will be elevated.
    - Microscopy may show hypersegmented neutrophils (6 or more lobes).
    - Serum folate will be low (< 3 ng/mL) early with deprivation followed by low RBC folate (< 150 ng/mL) which may lag for several weeks. RBC folate is more representative of total folate stores.
- To distinguish folic acid deficiency from B12 deficiency, treat with 100 to 500 μg folate daily. Reticulocytosis will be seen in 2 to 4 days. Treatment of B12 deficiency with folate may improve anemia but will not improve neurologic sequelae. If in doubt, treat both.

- Once B12 deficiency is ruled out, treat with folic acid (1 mg oral daily) supplementation.

Bone Marrow Stress or Failure

- **Aplastic anemia** occurs when bone marrow's ability for hematopoiesis is reduced or absent. It can be the result of acquired or congenital factors.
- **Bone marrow infiltration** is when bone marrow spaces are occupied by tumor, leukemia, fibrosis, or storage disease.
- **Dyserythropoiesis and myelodysplastic syndromes** result from ineffective erythropoiesis that presents with a decrease in one cell line and progresses to pancytopenia.
- Laboratory findings
  - Low RC.
  - Other cell lines are low or abnormal.
  - Microscopy may show teardrops, macrocytosis, or leukemic blasts.
  - Normal RDW.
  - Bone marrow examination for definitive diagnosis.
- Treatment is supportive and consists of transfusions and antibiotics until definitive care is available.

Liver Disease

- Signs and symptoms are consistent with liver disease.
- Laboratory findings
  - Microscopy will show burr cells or target cells.
  - Prolonged prothrombin time (PT) or activated partial thromboplastin time (aPTT) may be seen.
- Treatment consists of supportive care for coagulopathies and liver disease management.

Hypothyroidism

- Signs and symptoms are consistent with hypothyroidism, including weight gain, fatigue, cold intolerance, hair loss, constipation, depression, and weakness.
- Laboratory findings: spiculated, large red blood cells are evident on microscopy. Thyroid hormone levels will be low.
- Treatment consists of levothyroxine hormone replacement along with treatment of any underlying thyroid disorder.

Normocytic Anemias

Hemolytic Anemias

- The normal red blood cell lives for 120 days in circulation.
- Premature red blood cell destruction can result in anemia.
- Destruction can be intravascular or extravascular, inherited or acquired.
- Management is based on the specific etiology of hemolytic anemia. History and laboratory findings can help distinguish between the etiologies of hemolytic anemia.
- Laboratory findings
  - Normocytic, normochromic, or hyperchromic anemia.
  - Morphology of red blood cells can provide clues to the etiology (schistocytes, target cells, bite cells).
  - High RC.
  - High indirect bilirubin and lactate dehydrogenase.
  - Decreased haptoglobin.
  - Urinalysis will show hemoglobinuria.
  - Direct antibody testing would be positive in autoimmune hemolytic anemia.
  - Osmotic fragility testing would be abnormal in hereditary spherocytosis and other red cell membrane disorders.
  - Glucose-6-phosphate dehydrogenase (G6PD) activity would be low in G6PD deficiency. Levels may be normal during an acute hemolytic event and should be checked while a patient is not in active hemolysis.
- Physical examination will show scleral icterus, splenomegaly, and dark-colored urine.
- Differential
  - Enzymopathies (other than G6PD; see below).
  - Membranopathies, such as spherocytosis or elliptocytosis.
  - Autoimmune hemolytic anemias, such as
    - immune-mediated hemolysis, and
    - drug-induced hemolysis.
  - Microangiopathy, such as
    - hemolytic uremic syndrome,
    - disseminated intravascular coagulopathy, and
    - Kasabach-Merritt syndrome (large hemangiomas).

Glucose-6-Phosphate Dehydrogenase Deficiency

- G6PD functions as a reducing enzyme, is found in all cells, and has a normal half-life of 60 days. Most people with G6PD deficiency do not have symptoms.
- Red blood cells with reduced levels of G6PD have a shorter half-life and are susceptible to hemolysis when exposed to oxidative stress. Microscopy shows Heinz bodies.
- Inheritance is X-linked; males are much more likely to have symptomatic deficiency than females.
- Most patients with G6PD deficiency have descended from Africa (20% of all those from African descent), the Mediterranean (4%–30%), and Southeast Asia.
- Symptoms can be episodic. The African variant is often less severe than many Mediterranean and Asian subtypes.
- Diagnosis: assess G6PD level, which may be normal in the acute phase because all deficient red blood cells will have lysed.
- Treatment includes avoiding agents known to cause hemolysis (primaquine for malaria, sulfa drugs, etc; see www.g6pd.org for a complete list), supportive care for crises, and adequate hydration. Transfusions may be required.

Acute Blood Loss

- Control hemorrhage and manage acute trauma.
- Check for occult blood if the source of blood loss is not overt.

Transient Erythroblastopenia of Childhood

- Typical age of onset is about 2 to 3 years of age.
- Symptoms include pallor and tachycardia from profound anemia, but otherwise the patient appears well.
- Laboratory examination shows low RC. MCV is normal, but the patient may be macrocytic in early recovery.
- Treatment consists of supportive care.

Chronic Renal Disease

- Multifactorial anemia: chronic inflammation, nutritional deficiency, uremia, and decreased erythropoietin.

- Symptoms are consistent with renal insufficiency (dependent edema).
- Laboratory examination shows low RC and erythropoietin levels.
- Treatment consists of addressing the underlying renal disease. Erythropoietin or iron may be indicated in an advanced-care setting.

Sickle Cell Disease

- Inherited defects in beta (β) genes involved in Hgb production result in sickling of cells, vasoocclusion, inflammation, and multiorgan effects.
- Sickle cell disease shows a regional preference. It occurs frequently in people living in certain parts of Africa, India, and the Middle East; in the United States, it occurs in 0.2% of African Americans.
- Symptoms vary based on phenotype. Early recognition, education, and management are key to preventing further complications. Acute chest syndrome, stroke, and sepsis are deadly.
- Sickle cell disease is often found in the compound heterozygote state with other hemoglobinopathies.
  - More severe phenotypes/more frequent sequelae include homozygous Hgb SS disease, Hgb S/beta-zero thalassemia.
  - Less severe phenotypes/less frequent sequelae include heterozygous Hgb S/Hgb C disease, Hgb S/beta+ thalassemia.
- Symptoms vary based on phenotype and stressors.
  - Symptoms can include pain (vasoocclusive) crises:
    - Bony (most common locations are the lumbosacral spine, hip, femur, knee, shoulder, and elbow).
    - Dactylitis (swelling of distal extremities with pain) in infants.
    - Priapism.
    - Abdominal pain.
  - Rule out splenic sequestration (presents with weakness, splenomegaly, left-sided abdominal pain, and progressive shock; associated with a 30% mortality rate).

- Rule out gallstones, which are common during the second decade of life.
- Acute chest syndrome (multiple explanations are possible; this is common in older children).
  - Presents as fever with respiratory symptoms and a new infiltrate on radiography consistent with pneumonia.
  - Can be due to pulmonary fat embolism or an associated infection.
  - Pulmonary infarction is also a part of acute chest syndrome.
  - Often hypoventilation is attributable to narcotic administration or chest pain on breathing caused by infarction of rib or sternum.
- Ischemic stroke/transient ischemic attack.
- Developmental delays.
- Poor growth.
- Aplastic crisis (most often caused by parvovirus B19).
- Multiorgan dysfunction, evidenced by retinopathy, cardiac dysfunction and pulmonary hypertension, and immune dysfunction (functional asplenia).
- There is a risk of sepsis from encapsulated organisms (pneumococcal and meningococcal sepsis).

- Laboratory examination
  - RC is elevated (aplastic crisis is a concern if RC is decreased in the acute setting).
  - White blood cell count may be elevated.
  - Sickled cells or target cells (if concomitant thalassemia) are visible on peripheral blood smear.
  - Lactate dehydrogenase and indirect bilirubin are elevated.
  - Perform Sickledex (Strek, Inc, Omaha, Nebraska) or sickle prep solubility test.
  - Use Hgb electrophoresis for definitive diagnosis.
- Treatment in the deployed setting is limited to early recognition and management.
  - Ensure adequate hydration (free access to fluids, avoid overhydration).
  - Provide penicillin 125 mg oral twice daily for prophylaxis from pneumococcal infections until patient is 3 years old, then increase to 250 mg oral twice daily (lifelong prophylaxis is ideal).

- Ensure adequate nutritional support (multivitamin with folic acid supplementation).
- Encourage a comprehensive immunization program, including pneumococcal conjugate vaccine and meningococcal series.
- Hydroxyurea, if available, can often decrease long-term risk of complications (requires advanced care and monitoring).
- Pain should be managed aggressively.
  - Give nonsteroidal antiinflammatory drugs to decrease inflammation and pain.
  - Opioids and ketamine can be useful for pain management; consider patient-controlled analgesia, if available.
  - Abdominal or chest pain that is not well controlled can result in splinting and hypoventilation, which can lead to life-threatening sickling in the lungs (acute chest syndrome).
- Maintain oxygenation.
- Use bronchodilators and incentive spirometry for respiratory symptoms and pulmonary toilet.
- Administer antibiotics and aggressively evaluate any temperature greater than 38°C, giving broad-spectrum antibiotics (ceftriaxone) for fevers. Add azithromycin or fluoroquinolone for atypical coverage in the case of respiratory symptoms.
- Transfusions, including partial and complete exchange transfusions, may be necessary for emergency situations (eg, acute chest syndrome).

Thrombocytopenia

- Thrombocytopenia is a quantitative decrease in platelet count less than 150,000/mm^3 that may be secondary to decreased production, increased peripheral destruction, sequestration, or medication- or toxin-mediated myelosuppression.
- Thrombocytopenia results in bleeding, most commonly in mucous membranes, including epistaxis, oral bleeding, menorrhagia and increased bleeding with childbirth, and in the skin (including petechiae and bruising).
  - Increased bleeding may be seen in trauma or medical procedures for patients with platelet counts less than 100,000/mm^3.

- Spontaneous bleeding typically does not occur until platelet counts drop below 30,000/mm^3, and risks for spontaneous hemorrhage increase as numbers decrease.

- When to suspect thrombocytopenia (chief complaints):
  - Easy or spontaneous bruising and/or petechiae.
  - Recurrent or prolonged epistaxis.
  - Excessive bleeding with dental surgery or tonsillectomy.
  - Severe menorrhagia or excessive bleeding after childbirth.
- History
  - Considerations include age, recent illnesses, medication history, and potential toxin exposure.
  - Etiologies to consider in the newborn period:
    - Inheritable disorders of platelet production, including:
      - congenital amegakaryocytic thrombocytopenia,
      - thrombocytopenia-absent radius syndrome,
      - Fanconi anemia,
      - Bernard-Soulier syndrome (associated with large platelets),
      - May-Hegglin anomaly (giant platelets and pale-blue leukocyte inclusions),
      - grey platelet syndrome,
      - Alport syndrome,
      - Wiskott-Aldrich syndrome (small platelets, severe eczema), and
      - Gaucher disease.
    - Increased destruction, such as:
      - neonatal alloimmune thrombocytopenia and
      - viral or bacterial sepsis.
    - Platelet sequestration:
      - hypersplenism or
      - Kasabach-Merritt syndrome due to a hemangioendothelioma.
  - In the older child or teen, consider:
    - decreased production, including:
      - undiagnosed inheritable disorder of platelet production,
      - myleodysplastic syndrome or leukemia,
      - human immunodeficiency virus,
      - Lyme disease, and

        - other viral or infection suppression.
    - Increased destruction, including:
        - immune thrombocytopenic purpura (ITP),
        - thrombotic thrombocytopenic purpura,
        - viral or bacterial sepsis,
        - disseminated intravascular coagulation (DIC),
        - dengue fever,
        - systemic lupus erythematosus,
        - paroxysmal nocturnal hemoglobinuria,
        - hemolytic uremic syndrome, and
        - snakebites (particularly from pit vipers).
    - Medication- or toxin-mediated myelosuppression caused by (consult a pharmacist for a more comprehensive drug list):
        - valproic acid,
        - chemotherapeutic agents,
        - isotretinoin,
        - montelukast sodium,
        - heparin, and
        - some cephalosporins.
- Physical examination
    - Visually inspect the skin for evidence of bruising, purpura, or petechiae.
    - Visually inspect the mouth and nose for evidence of bleeding.
    - Dysmorphic physical features may suggest a genetic condition or inheritable disorder of platelet production.
    - Look for hemangiomas. If a child has multiple superficial hemangiomas, further imaging studies may locate larger internal hemangioendotheliomas responsible for Kasabach-Merritt Syndrome (platelet sequestration).
    - Splenomegaly can also suggest splenic sequestration.
    - Signs of anemia should be noted. When seen with symptoms of thrombocytopenia, consider a bone marrow process affecting multiple cell lines (leukemia), although viral infection is again still possible.
    - For significantly ill children (those with sepsis, shock, or mental status changes) consider DIC, hemolytic uremic syndrome (HUS), or thrombotic thrombocytopenic purpura (TTP).

- Laboratory evaluation: begin with a CBC and peripheral blood smear evaluation. A platelet count greater than 150,000/mm^3 is normal for all ages.

Diagnosis and Treatment

Immune (Idiopathic) Thrombocytopenic Purpura

- ITP is a common cause of thrombocytopenia in children, resulting when autoantibodies attack platelets. It may be acute or chronic and most commonly occurs between the ages of 2 and 8 years.
- ITP presents with bruising, petechiae, and mucous membrane involvement, including gum bleeding and epistaxis in a child who generally appears healthy. Rarely (in 10% of cases) splenomegaly will be present.
- Diagnosis
  - Patient will have a decreased platelet count, generally less than 20,000/mm^3 with normal Hgb and normal white blood cell counts.
  - Other coagulation studies (PT/aPTT) are normal.
  - Bone marrow studies show increased megakaryocytes; a bone marrow biopsy should be considered prior to steroid treatment in atypical cases or if additional cytopenias are present.
  - The presence of ITP for more than 12 to 18 months is considered chronic (chronic ITP occurs in 20% of patients with acute ITP).
- Treatment of acute ITP
  - Observe patient if platelet counts are greater than 20,000/mm^3 and there is no significant bleeding.
  - If platelet counts are less than 10,000/mm^3 or less than 20,000/mm^3 with bleeding:
    - Give prednisone 1 to 2 mg/kg/day, up to 60 mg/daily, tapered in 5- to 7-day intervals for 21 to 28 days.
    - Methylprednisolone 30 mg/kg/day, divided twice daily for 3 days, can be used for more severe cases.
    - Give anti-D immunoglobulin 50 to 75 μg/kg IV.
    - Administer IV immunoglobulin 0.8-1 g/kg if a more rapid increase in the platelet count is needed.

        - Premedicate with acetaminophen and diphenhydramine.
        - Infuse slowly over 4 hours, with epinephrine on hand in case an infusion reaction occurs.
    - Platelet transfusion should only be used for emergency, including surgery and intracranial hemorrhage, since transfused platelets will have a short life span.
    - Splenectomy is indicated for severe, life-threatening bleeding unresponsive to medical management (if possible, vaccination with meningococcal, pneumococcal, and *Haemophilus influenzae* type B vaccines should be given prior to splenectomy).
- Treatment of chronic ITP
    - Evaluate patients for evidence of other autoimmune diseases, such as systemic lupus erythematosus, hereditary bone marrow failure syndrome, or human immunodeficiency virus.
    - Treatment for symptomatic patients is the same as that for acute ITP.

Hemolytic Uremic Syndrome/Thrombotic Thrombocytopenic Purpura

- Both conditions are forms of microangiopathic anemia associated with thrombosis. Thrombus formation consumes platelets and hemolyzes red blood cells as they pass through small blood vessels.
- HUS is often seen in association with infections, including *Shigella dysenteriae* or *Escherichia coli* O157:H7.
- TTP can be seen following viral or bacterial infections, during pregnancy, or with certain drugs.
- Presentation
    - HUS: gastrointestinal infection, often including bloody diarrhea, oliguria, and hypertension.
    - TTP: bleeding with neurologic symptoms and later fever.
- Differentiation
    - Though both have thrombocytopenia and hemolytic anemia, HUS is typically less severe than TTP.
    - Platelet counts are greater than 100,000/mm^3 in more than 50% of patients.

- Age of onset is 6 months to 5 years in HUS, and generally adult-onset in TTP.
- Treatment
  - For HUS, treatment should be focused on the renal disease with fluid restriction and hypertension management. Packed red blood cell transfusions may be needed. Platelet transfusions are not indicated, as life-threatening bleeding is rare and platelet transfusion may worsen thrombosis.
  - Use plasmapheresis for TTP.

Disseminated Intravascular Coagulation

- DIC is an acquired syndrome of intravascular activation of the coagulation cascade that most commonly occurs following sepsis.
- Presentation
  - Bleeding, petechiae, or mucosal bleeding (may be minimal oozing or severe bleeding).
  - Laboratory abnormalities include prolonged PT and aPTT, decreased fibrinogen, and increased fibrin split products, including D-dimer, along with thrombocytopenia on CBC.
- Treatment
  - Treat the underlying cause and provide supportive care.
  - Transfuse platelets to maintain counts greater than 50,000/mm^3.
  - Administer fresh frozen plasma 10 to 15 mL/kg to maintain PT less than two times the upper limit of normal.
  - Administer cryoprecipitate to maintain fibrinogen greater than 100 mg/dL.

Inherited Coagulopathies

Hemophilia

Hemophilia A and B are x-linked deficiencies in factor VIII or factor IX, respectively. A rarer autosomal recessive deficiency in factor XI is known as Hemophilia C. These factors work together to drive the coagulation cascade from the intrinsic pathway to the common pathway.

- Presentation
  - Hemophilia A and B are clinically identical to each other and almost exclusively occur in males.

  - Initial manifestation can be prolonged and excessive bleeding after circumcision; therefore most patients are identified before 18 months of life.
  - Joint bleeding (hemarthrosis) is the hallmark of hemophilia, with weight-bearing joints of the legs being most frequently affected.
- Evaluation
  - PT will be normal but aPTT will be prolonged.
  - Factor assays will show decreased activity in the deficient factor.
  - Mixing study will correct if the patient has not developed inhibitors.
- Treatment
  - Factor replacement (Table 32-2).
  - Patients with mild or moderate factor VIII deficiency can be treated with desmopressin acetate 0.3 μg/kg IV over 15 to 30 minutes, or intranasal desmopressin acetate 1.5 mg/mL, 1 puff for children under 50 kg and 2 puffs for children greater than 50 kg.
  - Desmopressin acetate nasal spray for hemophilia is 15-fold more concentrated than the spray used for diabetes insipidus.
  - Beware of hyponatremia; avoid excess free water.

Table 32-2. Factor VIII and IX Levels Following Replacement*†

Type of Bleed	Desired Level (%)
Joint or simple hematoma	20–40
Simple dental extraction	50
Major soft tissue bleed	80–100
Head injury (prophylaxis)	100+
Major surgery (dental, orthopedic, other)	100+

*For factor VIII, each unit/kg will increase level by 2% (eg, to increase from < 10% to 100%, use 50 units/kg).
†For factor IX, each unit/kg will increase level by 1% (eg, to increase from < 10% to 100%, use 100 units/kg).

- If specific factors are unavailable or if the hemophilia is not known, then fresh frozen plasma 40 mL/kg can be used to control bleeding. Volume overload can be a complication, so for patients with hemophilia A, cryoprecipitate (50–100 units factor VIII/10 mL) can be used.
- Administer cryoprecipitate to maintain fibrinogen greater than 100 mg/dL.

Von Willebrand's Disease

Von Willebrand's Disease is the most common inherited bleeding disorder. It occurs in 1% to 2% of the population, though only a small number of affected individuals have clinically significant bleeding. It is an autosomal-dominant disorder, so often a strong family history of bleeding can be elicited.

- Presentation
  - History of bleeding and bruising similar to thrombocytopenia with mucocutaneous bleeding, epistaxis, menorrhagia, and bruising.
  - Oozing and post-operative bleeding in dental procedures and after tonsillectomy or adenoidectomy.
- Evaluation
  - Von Willebrand panel. Include von Willebrand activity and antigen, factor VIII level, and multimers. All are needed to differentiate between the six subtypes of von Willebrand's disease (I, IIa, IIb, IIm, IIn, and III).
- Treatment
  - For minor bleeding or prior to minor procedures, patients can be treated with desmopressin acetate 0.3 μg/kg IV over 15 to 30 minutes, or intranasal desmopressin acetate 1.5 mg/mL, 1 puff (150 μg) for children less than 50 kg and 1 puff in each nostril (330 μg) for those weighing over 50 kg.
  - To treat significant bleeding or for prophylaxis for major surgery, plasma-purified von Willebrand's factor or cryoprecipitate (50–100 units von Willebrand's factor/10 mL) should be used.

Oncology

- The most common malignancies in childhood include leukemia, brain tumors, lymphoma, neuroblastoma, Wilm's tumor of the kidney, bone tumors (such as Ewings sarcoma and osteosarcoma), and soft tissue sarcomas, like rhabdomyosarcoma.
- Children with cancer are particularly susceptible to infection, which is a significant cause for both morbidity and mortality in pediatric oncology patients.
- Etiology for this is multifactorial and includes a suppressed or abnormal immune system, poor nutritional status, mucous membrane damage (stomatitis and ulcers), and indwelling central venous catheters.
- In children with fever and neutropenia (an absolute neutrophil count less than 500 mm^3), broad-spectrum IV antibiotics with activity against both gram-negative and gram-positive organisms should be initiated within 1 hour of fever onset.
- Carefully examine the patient for a source of infection, paying particular attention to the mucous membranes, perineum, and skin surrounding the central venous catheter.
- The patient should be admitted until afebrile with no focus of infection and negative blood cultures for 48 to 72 hours, and have evidence of neutrophil recovery, with absolute neutrophil count greater than 200 mm^3 on at least two occasions separated by 24 hours and rising.
    - If a specific infection is identified, a full course of treatment should be undertaken.
    - If fevers persist for more than 3 to 5 days, or if a patient has a new fever after 3 to 5 days on broad-spectrum antibiotic therapy, antifungal therapy should be initiated and fungal infection should be evaluated, including taking fungal blood cultures, imaging, and examinations, excluding fungal disease in the eyes, sinuses, lungs, heart, liver, spleen, and skin.

Further Reading

1. *The Harriet Lane Handbook: A Manual for Pediatric House Officers*. 20th ed. Engorn B, Flerlage J, eds. Philadelphia, PA:Saunders/Elsevier; 2015.

Chapter 33

Pediatric Nephrology

Introduction

Acute kidney injury, electrolyte disturbances, nephrotic syndrome, and kidney stones are commonly encountered in austere environments or during humanitarian assistance operations. When there is any concern about effective renal function, determining the estimated glomerular filtration rate is paramount. This calculation is necessary when determining drug and antibiotic dosing as well as knowing when to avoid medications with renal toxicities, such as nonsteroidal antiinflammatory drugs (NSAIDs) and aminoglycosides.

There may be rare circumstances in which "field peritoneal dialysis" or renal biopsy may be contemplated, but they should be performed in conjunction with host-nation providers on a case-by-case basis after consultation with a pediatric nephrologist at a stateside medical treatment facility.

Hydration, volume repletion, and common electrolyte disturbances are addressed in Chapter 25, Basic Fluid and Electrolytes.

Assessing Kidney Function in Children

- The estimated glomerular filtration rate (eGFR) in mL/min/1.73 m^2 is calculated using the Schwartz formula.
  - Two data points are needed for the eGFR calculation: the patient's height (cm) and stable serum creatinine value.
  - Schwartz formula:

$$\text{eGFR} = \frac{(\text{height in cm})\,(k)}{(\text{serum dreatinine mg/dL})}$$

Where constant = k = 0.33 for premature infants,

= 0.45 for infants 1 to 52 weeks old

= 0.55 for all children 1 to 13 years old and adolescent females

= 0.7 for adolescent males 13 to 18 years old

- If an absolute increase in serum creatinine greater than 0.5 mg/dL is observed, treat eGFR as zero or less than 20 mL/min/1.73m^2.
- When kidney function is compromised, dose all medications based on eGFR. If eGFR is less than 40 mL/min/1.73m^2, especially in chronic kidney disease, associated conditions may include:
  - Anemia due to erythropoietin deficiency as well as the iron deficiency caused by chronic disease. Treat with iron supplementation and erythropoietin (if available).
  - Secondary hyperparathyroidism, as identified by high serum intact parathyroid hormone, phosphate, and alkaline phosphatase values, but low calcium values. Treat with calcium supplementation at meals to bind phosphate and raise calcium. If available, use 1,25-dihydroxyvitamin D to suppress intact parathyroid hormone.
  - Acidosis. Treat with sodium citrate (2–4 mEq/kg/day divided into three doses) and calcium carbonate supplementation (45–65 mg/kg/dose of elemental calcium divided three times per day with each meal) to neutralize H^+ ion and promote growth.
  - Hyperkalemia due to severe acidosis and decreased GFR. Treat with osmolar K^+-binding resin, such as sodium polystyrene sulfonate (1 g/kg/dose) every 6 hours as needed per os or per rectum to enhance potassium excretion. If urine output is present, consider a diuretic at high dose.

Acute Kidney Injury

- Acute kidney injury is evident when eGFR is less than 50 mL/min/1.73 m^2, or when creatinine rises by 0.5 mg/dL in children or 1.0 mg/dL in adolescents.
- The most common cause in the field or combat environment

is inadequate renal perfusion secondary to inadequate intravascular volume.
  - Use clinical examination to assess for inadequate intravascular fluid status.
    - Findings will include dry mucous membranes, sunken fontanelle, weight loss, etc.
    - Assess for shock by measuring heart rate, blood pressure (BP), and capillary refill time.
    - Check urine sodium if possible; urine sodium less than 20 mmol/L regardless of serum sodium indicates pre-renal azotemia.
    - Assess for high urine osmolarity or urine-specific gravity.
    - Assess oncotic pressure with serum albumin as a cause of low renal perfusion.
- Other causes of acute kidney injury in field environment include:
  - Obstructive uropathy: neurogenic bladder, posterior urethral valves, single kidney with renal stones, etc.
    - Look for lower extremity atrophy, sacral dimple, and hair tuft for spina bifida occulta, or for other signs of associated congenital anomalies.
    - Perform a kidney ultrasound to assess.
    - Place Foley catheter into bladder to address urinary flow.
    - Monitor serum creatinine after bladder decompression.
  - Acute glomerulonephritis (GN), evidenced by:
    - Hypertension
      - The correct BP cuff should measure two-thirds of the distance from olecranon to acromion; the bladder portion of the cuff should completely enwrap the arm.
      - Pediatric hypertension formula:

        < 12 months of age: > 100/70 mmHg

        Children 1–10 years old:

        – Systolic BP = age × (2.0) + 100 (95th percentile)

        – Diastolic BP = age × (1.5) + 70 (95th percentile)

        > 10 years of age: use adult blood pressure values

        - Proteinuria with acute hematuria (gross or microscopic). Red blood cell casts and dysmorphic red blood cells are present on microscopic urine evaluation (if available).
        - Edema.
    - Acute tubular necrosis. This presents the same as acute GN except granular casts are seen on microscopic urine evaluation.
- Treat acute kidney injury as follows:
    - Bolus initially with normal saline (NS) 20 mL/kg, blood products, or albumin 25% 0.5 to 1 g/kg slowly over 1 to 2 hours to establish intravascular volume and restore BP (**Caution**: Some patients may already be euvolemic or hypervolemic).
    - Place Foley catheter and record urine output.
    - Use one-third maintenance fluids (½NS without potassium) and replace the urine output hourly on a 1-to-1 basis with ½NS.
    - Control or maintain blood pressure with vasodilators or vasopressors based on the patient's BP.
        - For hypotension, use vasopressors.
        - For hypertension, consider diuretics or calcium channel blockers (**Caveat**: Do not use calcium channel blockers in infants less than 12 months of age because of the risk of severe cardiac compromise).
        - Titrate medications based on response.
            - If the patient becomes oliguric or anuric, consider furosemide, 3 to 5 mg/kg, to establish urine output to deal with volume overload.
            - Stabilize electrolytes, especially potassium (see Chapter 25 for hyperkalemia management).
            - Contact a nephrology consultant via the theater consult service, if possible.

Nephrotic Syndrome

- Diagnostic criteria
    - Hypoalbuminemia (< 2.5 gm/dL).
    - Proteinuria is when spot urine protein/creatinine ratio is greater than 2.0 **OR** urine dipstick or urinalysis shows 2+ protein or more.

- Hypercholesterolemia (total cholesterol greater than 200 mg/dL or low-density lipoprotein cholesterol greater than 130 mg/dL).
- Edema presenting with tibia and eyelid swelling (usually first signs), weight gain, and ascites.
- Notably absent: hypertension, elevated serum creatinine or decreased GFR, and active urine sediment (eg, no red blood cell casts, etc).

- Therapy
  - Treat edema if the following are present:
    - severe hyponatremia (< 125 mEq/L),
    - severe pleural effusion with respiratory distress, or
    - severe anasarca with skin breakdown or severe swelling in the scrotum or labial areas.
  - Administer "albumin-furosemide-albumin sandwich."
    - Albumin 25% 1 g/kg over 4 hours. Watch for declining respiratory status on cardiorespiratory monitor, if possible.
    - Follow with furosemide 1 mg/kg IV, then followed by the same dose of albumin again over 4 hours.
    - This treats edema by increasing oncotic pressure and renal perfusion and uses diuretic therapy to excrete free water.
  - Most cases of nephrotic syndrome will respond to prednisone at 2 mg/kg daily, to a maximum dose of 80 mg/day.
  - Nephrotic syndrome places the patient at risk for venous thromboembolic events. Encourage ambulation if possible and consider prophylaxis for deep vein thrombosis, especially if the patient is bedridden or if there is prolonged need for a central line.
  - Contact a nephrology specialist via the theater consult service if possible.

Renal Stones

- Renal stones are rare in children but austere environments create a risk for kidney stones due to climate and lack of potable water.

- Calcium oxalate stones are the most common type found in children.
- Clinical presentation is similar to adults and includes:
  - gross hematuria (pink or red in color);
  - inguinal or groin pain originating from the flank or abdomen;
  - obstructing stones that often cause infection behind the stone, evidenced by fever and flank pain; and
  - dysuria or a burning sensation if the patient passes gravel or stone.
- Evaluation for kidney stones consists of:
  - urinalysis (look for hematuria), and
  - renal ultrasound or computed tomography scan (if available).
  - If possible, check spot urine calcium-to-creatinine random level. A urine calcium-to-creatinine ratio greater than 0.2 is considered abnormal.
- Treatment
  - Hydrate with an extra 0.5 L/day of fluid in younger children (< 20 kg), at least 2 L/day in older children.
  - Maintain good urine output (five voids per day).
  - Consider citrate for increasing urine pH to solubilize stone-forming crystals.
  - Provide analgesia as needed.
  - Seek urology consultation, if available, for refractory pain or ureteral obstruction.

Chapter 34

Dermatology

Introduction

Most pediatric dermatological conditions are not acute and may be managed through telemedicine specialty consultation if dermatological expertise is needed. This chapter includes guidelines for telemedicine and focuses on situations requiring expeditious treatment in which potential delays in consultation may be deleterious to the patient.

Teledermatology Consultation

Requesting a teledermatology consultation is relatively easy for members of the US military. The following components should be submitted via e-mail to the US Army consultation service (derm.consult.army@mail.mil; be sure to remove the patient's personal information):

- Multiple focused photographs of all lesions on the patient.
  - Photographs are best taken in well-lit settings (natural sunlight is optimal), without use of the camera's flash.
  - Use the camera's "macro" setting, usually indicated by a picture of a flower, for close-up photographs of individual skin lesions.
- Basic dermatological history of a lesion or condition, including:
  - onset;
  - evolution;
  - duration;
  - location;
  - symptoms, such as itch or tenderness;
  - alleviating and exacerbating factors;
  - current skincare regimen, including hygiene and topical preparations; and
  - associated systemic symptoms.

- All treatments tried to date.
- Past medical history, including:
  - medications and allergies,
  - previous skin disease or cancer, and
  - systemic disease.
- Evidence of atopic background (eg, eczema, asthma, allergies).
- Family and social history, including:
  - skin diseases in other family members,
  - similar skin symptoms in close contacts, and
  - pertinent environmental exposures, such as climate, pets, chemicals, harsh soaps, abrasive brushes, or radiation.
- Results of Gram stain, potassium hydroxide preparation, or Tzanck smear, which may immediately elucidate bacterial, fungal, or viral infections, respectively (if available).
- Other laboratory test results that have been obtained (eg, complete blood count, cultures, or tissue specimens).

Begin a physical examination, checking vitals (especially fever) and general appearance. For a thorough skin examination, the patient should be fully disrobed and inspected from head to toe (eg, a common mistake is failing to examine the feet when a patient presents with hand dermatitis). To aid communication with the dermatologist, use the following descriptive terms:

- Primary skin lesions
  - Papule: an elevated, solid lesion up to 0.5 cm in diameter.
  - Plaque: a circumscribed, elevated, superficial, solid lesion greater than 0.5 cm in diameter.
  - Macule: a circumscribed, flat discoloration up to 0.5 cm in diameter.
  - Patch: a circumscribed, flat discoloration greater than 0.5 cm in diameter.
  - Nodule: a circumscribed, elevated, solid lesion greater than 0.5 cm in diameter; a larger, deeper papule.
  - Pustule: a circumscribed collection of pus (cloudy, free fluid, and leukocytes).
  - Vesicle: a circumscribed collection of free, clear fluid up to 0.5 cm in diameter.
  - Bulla: a circumscribed collection of free fluid greater than 0.5 cm in diameter; which may be flaccid (the blister does not appear full) or tense (the blister appears tight and full).

  - Wheal (hive): a firm, edematous, transient plaque, which lasts hours at most.
- Secondary changes, including:
  - Crust (scab): collection of dried serum and cellular debris.
  - Scale: excess dead epidermal cells, thickened stratum corneum.
  - Erosion: a partial focal loss of epidermis.
  - Ulcer: a full-thickness, focal loss of epidermis and dermis (deeper than erosion, heals with scarring).
  - Excoriation: an erosion caused by scratching, often linear.
  - Atrophy: depression in the skin resulting from thinning of the epidermis or dermis.
  - Lichenification: thickened epidermis induced by scratching (skin lines are accentuated).
- Special skin lesions include:
  - Telangiectasia: dilated superficial blood vessels (blanchable; empty completely with compression).
  - Petechiae: circumscribed deposit of blood less than 0.5 cm in diameter (not blanchable).
  - Purpura: circumscribed deposit of blood greater than 0.5 cm in diameter (not blanchable).
  - Erythema: an area of uniform redness that blanches with pressure.
- Other important descriptors include:
  - Color (eg, erythematous, violaceous, hemorrhagic, dusky, skin-colored, blanchable/nonblanchable, beefy red, yellow, etc).
  - Size (eg, 4 mm, 2 cm, etc).
  - Shape (eg, ill-defined oval, well-defined linear streak).
  - Specific location (eg, generalized over arms and legs but spares the trunk, face, and palms or soles).
  - A complete description also includes some comments on the mucous membranes (mouth, eyes, genitals, etc) and skin appendages (hair, nails).
- A response should be sent from a dermatologist within 24 hours (often in as few as 6–8 h).

Febrile Child With Rash

Many inflammatory diseases and viral exanthems may give this type of clinical picture. The following diagnoses include the majority of diseases that need to be recognized and treated emergently.

- Rickettsial diseases
  - Rocky Mountain spotted fever, Mediterranean spotted fever, typhus, and others.
  - Typically present with skin eruption, fever, headache, malaise, and prostration.
  - Transmitted by ticks, fleas, or body lice.
    - Original tick bite may be a clinical clue and often morphs from an inflamed papule to necrotic eschar (tache noir).
    - The skin eruption tends to become petechial as it progresses.
  - Diagnosis is based on which diseases may be endemic, the clinical presentation, and indirect fluorescent antibody testing, which may be confirmed by Western blot.
  - It is imperative, especially for the spotted fever group of rickettsial diseases, to treat presumptively with oral doxycycline, as the intravenous (IV) formulation is unlikely to be available in theater (2.2 mg/kg/dose bid IV or oral, maximum dose 100 mg bid; Figure 34-1).
- Meningococcemia
  - Typically presents acutely, with fever, chills, hypotension, and meningitic symptoms (eg, neck stiffness, photophobia).
  - Half to two-thirds of patients develop a petechial or ecchymotic eruption, primarily on the trunk and lower extremities, as well as petechiae on the eyelids and acral surfaces (Figure 34-2).
  - The petechial eruption tends to progress to hemorrhagic bullae or frank necrosis.
  - Diagnosis is made on clinical suspicion because treatment must be rapid.
    - Blood cultures growing the gram-negative diplococci of *Neisseria meningitidis* confirm the diagnosis.
    - Treat these patients emergently with aqueous penicillin G (100,000–400,000 units/kg/day divided every 4–6 h,



Figure 34-1. Rocky Mountain spotted fever. Child's right hand and wrist displaying the characteristic spotted rash of Rocky Mountain spotted fever. Rocky Mountain spotted fever is the most severe and most frequently reported rickettsial illness in the United States. The disease is caused by *Rickettsia rickettsii*, a species of bacteria that is spread to humans by ixodid (hard) ticks.
Reproduced from Centers for Disease Control and Prevention, Public Health Image Library. Image 1962. http://phil.cdc.gov/phil. Accessed August 24, 2015.

maximum dose of 24 million units/day) or ceftriaxone (100 mg/kg/day divided every 12 h IV, maximum dose 2 g/day) for 7 days. If the diagnosis is suspected, do not wait for cultures to confirm.
    - Close contacts should receive prophylactic rifampin (children) or ciprofloxacin (adults).
- Measles (rubeola)
    - A prodrome of high fever, malaise, conjunctivitis, cough, and coryza (head cold symptoms) is followed by a maculopapular eruption (ie, generalized erythematous macules and papules), which begins on the head and progresses down the body over 2 to 3 days (Figure 34-3).
    - Koplik spots (white papules on an erythematous background on the buccal mucosa) are pathognomonic and appear during the prodrome, lasting 3 days (Figure 34-4).



Figure 34-2. **(a)** 10-month-old female with high fever and rapidly spreading petechial-purpuric rash and septic shock. Blood culture grew *Neisseria meningitidis*. She did not survive despite antibiotics and early aggressive treatment of her shock. **(b)** 14-year-old boy with acute onset of fever and rapidly developing petechial rash starting on lower extremities and buttocks and generalizing. Blood culture grew *Neisseria meningitidis*. He was treated with ceftriaxone in the intensive care unit for severe sepsis and survived, only requiring skin grafts over areas of extensive ecchymoses.
Photographs courtesy of Martin Weisse, Colonel, Assistant Director of Pediatrics, Defense Health Agency National Capital Region Medical Directorate. From the library of JW Bass.



Figure 34-3. Measles. This child with measles is showing the characteristic red blotchy rash on his buttocks and back during the third day of the rash. Measles is an acute, highly communicable viral disease with prodromal fever, conjunctivitis, coryza, cough, and Koplik spots on the buccal mucosa. A red blotchy rash appears around day 3 of the illness, first on the face, then becoming generalized.
Reproduced from Centers for Disease Control and Prevention, Public Health Image Library. Image 4497. http://phil.cdc.gov. Accessed August 26, 2015.

    - See Chapter 29, Infectious Diseases, for full discussion of measles.
- Scarlet fever
    - Caused by toxins of group A streptococcal infection.
    - Primarily affects children under 10 years old and was often fatal before the era of antibiotics.
    - Presents with sore throat (Streptococcus pharyngitis or tonsillitis), malaise, headache, nausea, abdominal pain, and high fever; an erythematous, blanchable, sandpaper-like rash follows within 12 to 48 hours.
    - The eruption looks like "a sunburn with goose pimples," and begins on the neck, groin, and axillae before spreading to the rest of the body (Figure 34-5).

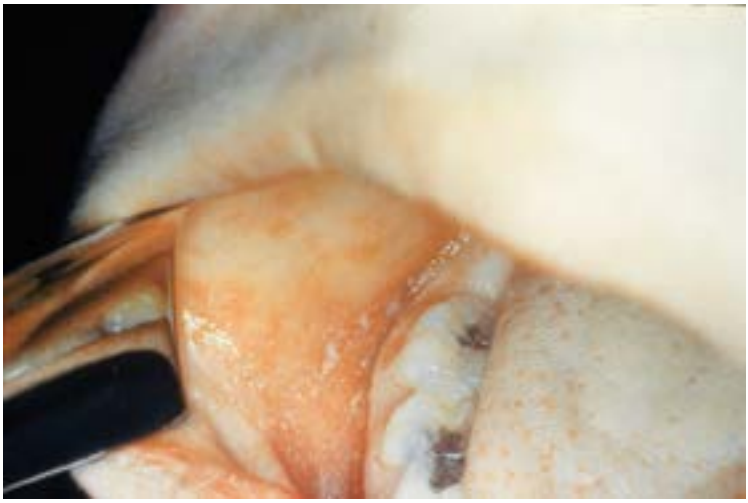


Figure 34-4. Measles with Koplik spots. This patient presented on the third pre-eruptive day with "Koplik spots" indicative of the onset of measles. Koplik spots occur 1 to 2 days prior to eruption of the rash and last 1 to 2 days after the cutaneous rash erupts. They appear as punctate blue-white spots on a bright red background of the oral buccal (cheek) mucosa. Their presence is considered to be pathognomonic for measles.
Photograph courtesy of Scott Norton, MD, MPH, MSc, Division Chief, Dermatology; Children's National Health System, Washington, DC.

- Pastia sign, petechial linear streaks within flexural creases, may also be seen.
- Palms, soles, and conjunctivae are typically unaffected.
- In addition to the pharyngitis, the child may have circumoral pallor, cervical lymphadenopathy, palatal petechiae, and white strawberry tongue, which later morphs into red strawberry tongue.
- Diagnosis is clinical, though a throat culture may be useful.
- Treatment with penicillin or amoxicillin should be initiated to prevent the development of rheumatic fever.
- Desquamation typically occurs 7 to 10 days after the eruption and should not be cause for concern.
- Complications include otitis, peritonsillar abscess, pneumonia, myocarditis, meningitis, and arthritis, as well as the immune sequelae of glomerulonephritis and



Figure 34-5. This patient revealed a scarlet fever rash on the volar surface of the forearm due to group A Streptococcus bacteria. The scarlet fever rash first appears as tiny red bumps on the chest and abdomen, then may spread all over the body. It looks like a sunburn, feels like a rough piece of sandpaper, and lasts about 2 to 5 days.
Reproduced from Centers for Disease Control and Prevention, Public Health Image Library. Image 5163. http://phil.cdc.gov. Accessed August 26, 2015.

rheumatic fever. Consider measles, toxic shock syndrome, drug hypersensitivity, staphylococcal scalded skin, and Kawasaki disease in the differential.

- Kawasaki disease (mucocutaneous lymph node syndrome)
  - Kawasaki disease is typically seen in children older than 5 years. It is diagnosed by the presence of fever for more than 5 days plus four of the following diagnostic criteria:
    - Polymorphous skin eruption (ie, a rash that may take many shapes). An erythematous, desquamating perianal rash is often an early sign. As the illness progresses over 10 to 20 days, fingers and toes may desquamate, starting around the nails.
    - Stomatitis (injected pharynx, strawberry tongue, fissuring cheilitis).
    - Edema of the hands and feet.

    - Conjunctival injection (nonpurulent).
    - Cervical lymphadenopathy.
  - Treatment
    - Although intravenous immunoglobulin (IVIG) is the treatment of choice, it is unlikely that it will be available in theater. When it is used, infuse 2 g/kg over 12 hours and monitor.
    - Evacuation to a higher level of care is appropriate.
    - Aspirin is concomitant therapy and may also be considered in the absence of IVIG therapy. Initial treatment is dosing at 80 to 100 mg/kg/day divided into four doses. When the patient is afebrile for 48 hours, change to 3 to 5 mg/kg/day for 6 to 8 weeks.
- Toxic shock syndrome can be caused by either Streptococcus or Staphylococcus.
  - Streptococcal toxic shock syndrome presents with fever, shock, multiorgan system failure, and usually soft-tissue infection, such as necrotizing fasciitis.
    - Streptococcal toxins have direct effects on the major organs, leading to shock and, ultimately, a mortality rate of 30%.
    - Do not wait for cultures; treat emergently with fluids and pressors as needed if available.
    - Also give clindamycin (40 mg/kg/day divided every 6–8 h) and surgically debride any soft-tissue infection source if possible.
  - Staphylococcal toxic shock syndrome, caused by an exotoxin of *Staphylococcus aureus*, is typically associated with a staphylococcal wound or catheter infections, or with surgical or nasal packing.
    - Patients present with sudden onset of high fever, myalgias, vomiting, diarrhea, headache, and pharyngitis; progression to shock can be rapid and fatal.
    - Patients typically develop a diffuse scarlatiniform exanthem, erythema, and edema of the palms and soles, strawberry tongue, hyperemia of the conjunctiva, and a nonpitting generalized edema.
    - Treat with supportive care and penicillinase-resistant antibiotics; remove any nidus for infection, such as nasal packing, tampons, and catheters.

    - When considering toxic shock syndrome, also include Kawasaki disease, scarlet fever, staphylococcal scalded skin syndrome, toxic epidermal necrolysis, systemic lupus, rickettsial spotted fevers, and leptospirosis in the differential diagnosis.
    - Desquamation of the palms and soles typically follows toxic shock syndrome by 1 to 3 weeks.
- Lyme disease is mainly caused by *Borrelia burgdorferi* and is transmitted by *Ixodes* species ticks.
    - It occurs in the United States and Europe, and sporadic cases have been reported in Asia and Northern Africa.
    - Early localized disease is characterized by local infection at the site of the tick bite, usually manifested as the "bull's eye" rash of erythema migrans (Figure 34-6), about 10 days after the bite. Only 80% of patients develop the rash, and it is less common in European cases.
    - Fever, malaise, body aches, and flu-like symptoms may occur.
    - See Chapter 29, Infectious Diseases, for more information on the various presentations, diagnostic criteria, and treatment of Lyme disease.
    - Treatment for most people with early localized infection is oral administration of doxycycline, which is contraindicated in children younger than 8 years old. Alternatives include amoxicillin, cefuroxime axetil, and azithromycin.

Bullae, Erosions, and Desquamation in Neonates and Young Children

The differential diagnosis for bullae in the neonate is vast and may include a variety of incurable genetic disorders that must be managed with intensive supportive care. For this reason, in the deployed setting, it is best to determine if the bullae are related to something acute or treatable, such as bullous staphylococcal impetigo or acute burn injury.

- Bullous staphylococcal impetigo
    - Bullous staphylococcal impetigo can be life-threatening in neonates and often occurs between the fourth and tenth days of life.



Figure 34-6. Lyme disease (erythema migrans). This depicts the pathognomonic erythematous rash in the pattern of a "bull's-eye," which manifested at the site of a tick bite on this Maryland patient's posterior right upper arm. A key component of early diagnosis is recognition of the characteristic Lyme disease rash, erythema migrans. This rash often manifests itself in a "bull's-eye" appearance, and is observed in about 80% of Lyme disease patients.
Reproduced from Centers for Disease Control and Prevention, Public Health Image Library/James Gathany. Image 9875. http://phil.cdc.gov. Accessed August 26, 2015.



Figure 34-7. Staph scalded skin syndrome. This toddler presented with a 1-day history of fever, painful skin, and spreading red rash over her entire body. There was no specific focus of infection. Note the denuded blisters and peeling skin over the entire back. Nasal culture grew *Staphylococcus aureus* (methicillin-sensitive *S aureus*). She rapidly improved with nafcillin therapy. Photograph courtesy of Scott Norton, MD, MPH, MSc, Division Chief, Dermatology; Children's National Health System, Washington, DC.

- Bullae may appear on any part of the body, often starting on the face or hands. Intertriginous areas are commonly involved.
- Weakness, fever, and diarrhea may follow; sepsis may occur without antistaphylococcal antibiotics.

- Staphylococcal scalded skin syndrome (Figure 34-7)
  - Staphylococcal scalded skin syndrome preferentially affects neonates and young children.
  - It begins with abrupt fever, skin tenderness, and erythema involving the neck, groin, and axillae.
  - Over the next few hours to days, erythema progresses to cover more surface area, before ultimately evolving into a very superficial, generalized desquamation (more superficial and less severe than in toxic epidermal necrolysis).
    - Large sheets of epidermis separate.
    - Nikolsky sign is positive (the upper layer of the skin detaches with application of lateral fingertip pressure to intact skin adjacent to a lesion).
    - The affected skin extends far beyond areas of actual infection (usually the pharynx, nose, ear, conjunctiva, skin, or septicemia).
  - Cultures are best taken from the mucous membranes, although they may be negative.
  - Rapid diagnosis can be made by examining frozen sections of a skin biopsy from a blister, though in theater the diagnosis is clinical.
  - Treatment includes IV fluids and cefazolin (50–100 mg/kg/day IV divided every 8 h, maximum dose 6 g/day; adjust for methicillin-resistant *S aureus* as necessary, according to cultures).
- Neonatal herpes simplex virus (HSV) can also be life-threatening.
  - Neonatal HSV presents with vesicles in the newborn (Figure 34-8).
  - The majority of transmission occurs during delivery, and almost all patients present at 4 to 21 days of life.
  - It may be localized to the skin and/or eye, involve the central nervous system, or be disseminated (encephalitis, hepatitis, pneumonia, coagulopathy).



Figure 34-8. Note the grouped vesicles on one hand. A Tzanck smear was positive and a viral culture confirmed the diagnosis of herpes simplex virus infection.
Photograph courtesy of Brian P Green, Major, Medical Corps, US Army; Walter Reed National Military Medical Center, Bethesda, MD.

        - Encephalitis or disseminated HSV can be fatal in up to half of affected neonates.
        - More than half of survivors sustain neurological disability.
    - Classic HSV presentation involves painful clusters of vesicles on an erythematous base; however, in over a third of cases, vesicles may not be seen.
        - Clusters of erosions tend to remain where vesicles were located. When these clusters coalesce, they leave behind an erosion or shallow ulcer with scalloped borders.
    - Confirmation with a Tzanck smear or more specific immunofluorescence testing is ideal, but it is often unavailable in theater.
    - If neonatal HSV is suspected, begin IV acyclovir (60 mg/kg/day IV divided every 8 h for 21 days) immediately; ensure adequate hydration to avoid renal injury.
- Bullous drug reactions can vary dramatically in severity and many dermatologists consider drug-induced erythema multiforme, drug-induced Stevens-Johnson syndrome (SJS), and toxic epidermal necrolysis (TEN) to represent variations of the same disease process but on a spectrum of severity (Figures 34-9 and 34-10).
    - The definitions of SJS and TEN are somewhat arbitrary and overlap exists; usually SJS affects less than 10% body surface area and TEN affects greater than 30% body surface area.
    - The more widespread and severe the epidermolysis, the worse the prognosis and the more likely the process is drug-induced.
    - The separation of skin layers in TEN is deeper than that in staphylococcal scalded skin syndrome (see above), with resultant denudation comparable to widespread burns. Accordingly, patients with TEN require supportive care in an intensive care unit or burn center.
    - Patients with SJS have a better prognosis than those with TEN, but whether the mucocutaneous denudation is due to TEN or SJS, offending drugs should be discontinued immediately and the patient should be transferred to an intensive care unit for careful fluid management, wound care, nutritional support, and sepsis precautions.



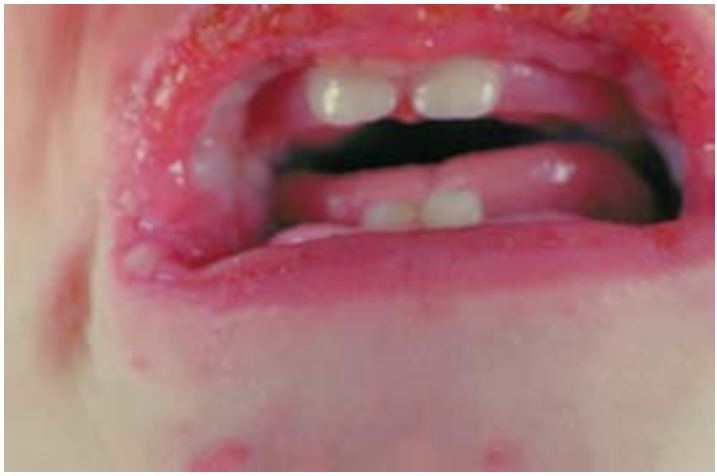
Figure 34-9. This image depicts the right arm of a 6-month-old boy who, after having received a primary smallpox vaccination, developed toxic epidermal necrolysis. Many people develop skin rashes after vaccination, almost all of which are benign. Rarely, a more serious eruption, like toxic epidermal necrolysis or its milder counterpart, Stevens-Johnson syndrome, may occur, requiring more aggressive therapy that may include steroids. If possible, a dermatology consultation should be obtained before initiating steroid therapy.
Reproduced from Centers for Disease Control and Prevention, Public Health Image Library/Arthur E Kaye. Image 3284. http://phil.cdc.gov/phil. Accessed August 26, 2015.

a



Figure 34-10. **(a)** Erythema multiforme major, also referred to as Stevens-Johnson syndrome, is a toxic or allergic rash in response to some vaccines or medications (it can also be idiopathic). It can take various forms, be mildly pruritic, and range from moderate to severe. When the lesions fade, a faint purple-pink hue can remain, helping differentiate it from urticaria (hives), which will leave no trace.
Reproduced from Centers for Disease Control and Prevention, Public Health Image Library/Allen W Mathies, MD, John Leedom, MD/California Emergency Preparedness Office, Immunization Branch. Image 4653 (a) and 4650 (b). http://phil.cdc.gov/phil. Accessed August 26, 2015.

b



(b) Same patient. Note mucosal involvement.

- Early ophthalmologic intervention is needed to avoid ocular scarring and blindness.
- The use of systemic corticosteroids and IVIG for either disease is controversial. The best treatment in theater is evacuation to a higher level of care.

- Erythema multiforme (minor) typically occurs in the spring or fall, and is often associated with HSV or, less commonly, *Mycoplasma pneumoniae*.
  - The lesions can have many different morphologies (hence "multiforme"), but are often targetoid in nature and can be acral in location (Figure 34-10a).
  - Most cases are self-limited and do not require treatment.
  - Daily suppressive anti-HSV therapy may be considered if the erythema multiforme recurs frequently (eg, acyclovir).
- Severe contact dermatitis can also present with widespread erythema and bullae.
  - Even when severe and widespread, contact dermatitis typically displays a patterned distribution.
  - It is very pruritic.

        - In severe cases, patients may require a 3- to 4-week taper of oral corticosteroids.
        - Encourage good skin hygiene (at least twice daily gentle cleansing, if possible, followed by bland emollient, such as petrolatum).
    - Antistaphylococcal antibiotics may also be necessary in cases of secondary infection (suggested by tenderness, expanding honey-colored crusts, and a positive bacterial culture).
- Atopic dermatitis (eczema)
    - Eczema is a common inflammatory skin disease in childhood characterized by intense pruritus and cutaneous inflammation.
    - In addition to affecting quality of life, atopic dermatitis can lead to disruption of the skin barrier and increase susceptibility to infection.
    - It can be associated with asthma and seasonal allergies (the atopic triad).
    - Exacerbating factors may include irritants (soap, overwashing, drying chemicals) and allergens (skin contact is far more detrimental than contact with foods or aeroallergens).
        - Presentation in infants and toddlers: erythematous papules and plaques often with overlying excoriation, crusting, and serous exudates; distribution is usually over the scalp, forehead, cheeks, trunk, and extensor surfaces of the extremities.
        - Presentation in children and adults: dry, intensely pruritic papules and patches on flexor surfaces of the arms, neck, and legs. The dorsum of the hands and feet are often involved.
    - Secondary changes are often seen, such as lichenification and postinflammatory hypopigmentation and hyperpigmentation.
    - The differential diagnosis includes seborrheic dermatitis, psoriasis, pityriasis rosea, candidiasis, and keratosis pilaris.
    - Treatment:
        - Avoid known allergens and irritants.
        - Soak and smear: hydrate the skin by soaking in lukewarm water for 20 minutes; follow immediately

(while the skin is still damp) by sealing in the moisture with emollient (ointment, cream, or thick lotion). Moisturize frequently with less greasy lotions between soak-and-smear treatments.
    - Use only mild soaps when necessary.
    - Apply topical corticosteroids to localized plaques; taper off the steroids as the plaques clear.
    - Avoid topical steroids on the face and on open wounds.
    - Use oral corticosteroids only in very severe cases (there is the potential for a rebound effect upon discontinuation).
    - Use topical or oral antibiotics directed against *S aureus* for superinfection.
- Smallpox (variola major) has theoretically been eradicated since 1977, but is mentioned here due to its potential as a bioterrorism threat (smallpox was fatal in up to 40% of untreated patients).
    - Smallpox is characterized by fever, severe headache and backache, and enanthem followed by exanthem.
    - Lesions progress simultaneously from erythematous macules to papules to vesicles, and finally pustules, which crust and collapse.
        - This progression takes approximately 2 weeks.
        - The lesions first appear on the palms and soles, then spread to the face and extremities (Figure 34-11).
    - By contrast, varicella (chickenpox) presents with lesions in varying stages of development (macules, papules, vesicles, crusts) and tends to involve the trunk and face preferentially.
        - Varicella lesions evolve from vesicle to crust within 24 hours.
        - Varicella can be identified at the bedside with a Tzanck smear, but a smear for direct fluorescent antibody staining and a viral culture confirm the diagnosis.
    - Smallpox can be definitively diagnosed by viral culture, polymerase chain reaction, or electron microscopy; however, based on clinical suspicion, patients thought to have smallpox should be isolated, receive supportive care, and be attended only by properly vaccinated healthcare workers.



Figure 34-11. Smallpox. Depicted in this 1974 photograph is a Bengali boy who was an inhabitant of a Bangladesh village. As evidence from this image, he had sustained the ravages of smallpox, with the classic maculopapular rash evident on his torso and arm.
Reproduced from Centers for Disease Control and Prevention, Public Health Image Library/Jean Roy. Image 10661. http://phil.cdc.gov. Accessed August 26, 2015.

- Smallpox is spread by the respiratory route and patients are infectious from the onset of enanthem until about 10 days after the eruption begins (lesions are crusted).
- Patients with varicella should also receive supportive care; 20 mg/kg tid acyclovir over 5 days may speed recovery if initiated within 24 hours of the appearance of the eruption.
  - Acyclovir should always be given to children over 13 years old and to any child with a history of atopic dermatitis.
  - Aspirin should never be given to varicella patients because of the risk of Reye's syndrome (fulminant hepatitis and encephalopathy).

- Purpura in children
  - Henoch-Schönlein purpura (anaphylactoid purpura or allergic vasculitis; Figure 34-12) is the most common leukocytoclastic vasculitis in children ages 4 to 8 years old (predominantly males).
    - The trigger is often viral infection or streptococcal pharyngitis, as well as food, drugs, and lymphoma.
    - The rash is characterized by palpable purpura on the arms, legs, and buttocks.
    - Patients can also have mild fever, abdominal colic, bloody stools, and arthralgias.
    - Renal involvement with microscopic or gross hematuria is seen in half of patients, and a small percentage of patients go on to develop renal failure.
    - Fatal pulmonary hemorrhage complicates rare cases.
    - Diagnosis is clinical.
    - Purpura typically lasts 6 to 16 weeks.
    - Treatment is supportive, though oral corticosteroids can be given for abdominal pain.
      - IVIG can be used in extreme cases.
      - Nonsteroidal antiinflammatory drugs should be avoided (they may exacerbate renal or gastrointestinal problems).
  - Purpura fulminans is a rapid, dramatic, and often fatal reaction seen in children (Figure 34-13).
    - It may be categorized as neonatal, idiopathic, or acute infectious (eg, *N meningitides*, Staphylococcus, and Streptococcus).



Figure 34-12. Henoch-Schönlein purpura. This previously healthy boy developed palpable purpuric lesions on his extremities, face, and buttocks 2 weeks after an upper respiratory infection. He subsequently experienced swelling of his ankles and wrists, colicky abdominal pain, and hematuria. His skin eruption and associated symptoms recurred for 3 weeks before resolving without complications.
Photograph courtesy of Scott Norton, MD, MPH, MSc, Division Chief, Dermatology; Children's National Health System, Washington, DC.

  - The appearance of widespread ecchymoses on the extremities, followed by frank acral necrosis, is characteristic.
  - Disseminated intravascular coagulation (DIC) typically follows an infectious process, such as scarlet fever, meningitis, pneumonia, or superinfected varicella.
- Treatment is supportive and best managed in the intensive care unit.
- Many patients die from this complication and others require amputations.



Figure 34-13. Purpura fulminans due to a fatal case of meningococcemia in 6-month-old child.
Photograph courtesy of Martin Weisse, Colonel, Medical Corps, US Army, Assistant Director of Pediatrics, Defense Health Agency National Capital Region Medical Directorate. From the library of JW Bass.

- Necrosis in children
  - Necrotizing fasciitis, or "flesh-eating bacteria," is most commonly caused by β-hemolytic streptococci, though other organisms, both aerobic and anaerobic, can be causative.
  - Bacteria typically enter through a surgical or puncture wound, but necrotizing fasciitis may also occur de novo.
  - Within 24 to 48 hours, as the bacteria spread along fascial planes and destroy tissue, the involved skin progresses from red, painful edema to dusky blue, anesthetic skin, with or without serosanguineous blisters.
  - An early clue of necrosis is tenderness outside the area of cellulitis.
  - By the fourth or fifth day, the purple areas become gangrenous.
  - Patients present in severe pain and are often hypotensive with leukocytosis.

- Mortality is around 20%.
- Prompt surgical intervention is necessary to conserve tissue and preserve the life of the patient.
- Neonatal necrotizing fasciitis most commonly affects the abdominal wall and incurs a higher mortality rate than fasciitis in adults.

- DIC
  - DIC presents with widespread intravascular coagulation and, in two-thirds of patients, skin eruption of petechiae and ecchymoses, with or without hemorrhagic bullae.
  - Purpura fulminans may supervene.
  - DIC can be due to a number of disorders, including sepsis, arthropod venom, obstetric complications, and acidosis.
  - Supportive care and replacement of appropriate coagulation factors (including vitamin K) and treatment with IV heparin are necessary for patients with DIC.
- Anthrax
  - Anthrax may pose a bioterrorism threat, but it typically occurs from the handling of animal hides or from contact with infected animals (alive or dead).
  - Patients present with a rapidly necrosing, painless eschar with suppurative regional adenitis (Figure 34-14).
  - Anthrax may be cutaneous (most common), inhalational, or gastrointestinal.
  - Cutaneous anthrax begins as an inflamed papule at the inoculation site.
    - The papule progresses to a bulla with surrounding edema.
    - The bulla ruptures to leave behind a dark brown or black eschar, surrounded by vesicles over a red, hot, swollen base.
  - Although regional lymph nodes may be tender, the anthrax lesion itself is painless.
  - In about 20% of untreated cases, patients may develop high fever, collapse, and eventually die over days to weeks.
  - Diagnosis is made by identifying the gram-positive bacillus in smears or culture.
  - Treat early with ciprofloxacin or doxycycline for 60 days.
    - If the child is less than 2 years old, treat intravenously, if possible.



Figure 34-14. Anthrax. Anthrax lesion on the skin of the forearm caused by the bacterium *Bacillus anthracis*. Here the disease has manifested itself as a cutaneous ulceration, which has begun to turn black, hence the origin of the name "anthrax," after the Greek name for coal.
Reproduced from Centers for Disease Control and Prevention, Public Health Image Library/James H Steele. Image 2033. http://phil.cdc.gov. Accessed August 26, 2015.

- Asymptomatic exposed individuals should be given 6 weeks of prophylactic doxycycline or ciprofloxacin.

Further Reading

1. VisualDx. LearnDerm webpage. Rochester, NY: VisualDX. www.learnderm.org. Accessed February 13, 2015. Tutorial takes approximately 1½ hours and encompasses the essentials of the skin examination, including describing morphology and recognizing patterns of distribution and configuration.
2. VisualDx website. Rochester, NY: VisualDX. www.visualdx.com. Accessed February 13, 2015. From any US military computer, click on the login tab (US military has purchased access). Comprehensive source of skin lesion photos. May enter diagnosis or key words to search to get a visual differential.

Chapter 35

Malnutrition and Emergency Nutrition for Sick or Injured Infants and Children

Introduction

Clinicians in austere environments must be prepared to nutritionally support critically ill or injured children, seriously ill children with underlying malnutrition (who have a higher associated morbidity and mortality than those who are appropriately nourished), and occasionally larger populations of children with chronic protein-energy malnutrition. This latter group may be numerous in a complex humanitarian emergency. In these situations, US military providers are most likely to play a support role, while nongovernmental and other relief agencies take the lead. Understanding key features and management principles for these situations is crucial to maximizing patient outcomes.

Assessment Methods for Height, Weight, and Nutrition Status

- Estimating height and weight:
  - In the absence of severe malnutrition, the Broselow Pediatric Emergency Tape (see back inside cover of this book) has been shown to provide an accurate and rapid estimation of ideal child weight in emergencies.
  - Detailed nutritional assessments and trending of clinical progress should use either weight for height percentiles or weight for height z score.
  - Age- and length-based norms for weight are published by the World Health Organization (WHO). A rapid synopsis for use in emergencies is presented in Table 35-1.

Table 35-1. Average Weights and Heights for Age and Gender*

	Males		Females	
Age	Length/Height (cm)	Weight (kg)	Length/Height (cm)	Weight (kg)
2–6 months	62	6	62	6
7–12 months	72	9	71	8
1–3 years	87	12	86	12
4–8 years	116	20	115	20
9–13 years	143	36	145	37
14–18 years	173	61	163	54
19–30 years	177	70	163	57

*World Health Organization norms.

- Mid-upper arm circumference (MUAC) is a screening tool used to measure acute malnutrition in children ages 6 to 60 months, without edema, using the circumference of the child's mid-upper arm (Table 35-2).

Table 35-2. Mid-Upper Arm Circumference Screening for Malnutrition

MUAC Measurement	Degree of Malnutrition
< 115 mm	Severe acute malnutrition
≥ 115 and < 125 mm	Moderate acute malnutrition
≥ 125 mm	Not acutely malnourished

MUAC: mid-upper arm circumference

Calorie and Protein Needs

- Overall nutritional goals for sick or injured infants and children are to provide sufficient calories and protein to spare mobilization of body reserves (prevent catabolism), promote wound healing, and protect from infection.
- Calorie needs are generally lower in the initial phase of trauma or critical illness because of:
  - lack of activity,
  - decreased metabolic rate, and

  - the body becoming catabolic, which inhibits use of calories for growth.
- Calorie needs will increase as the infant or child becomes more stable. Exogenous calories and protein can be used to promote anabolism.
- The metabolic stress of serious illness and injury results in increased protein breakdown, which can cause a negative protein balance if at least 1.5 gm/kg of dietary protein is not provided.
- Protein needs are even higher in sick infants and children with open wounds, burns, or losses (eg, diarrhea or ostomy output).
- Calorie and protein needs are best calculated using the child's actual weight.
- It is important to avoid underfeeding, which can compromise healing, as well as overfeeding.
  - Overfeeding can cause metabolic and respiratory stress, leading to hyperglycemia, diarrhea, tachypnea, hypercarbia, and failure to wean off mechanical ventilation.
  - Calculations for estimating energy needs are not exact. Overfeeding should be considered whenever a patient on nutritional support exhibits any of the above signs and symptoms.
- A patient's total energy expenditure can be calculated using the following equation and Tables 35-3 and 35-4 as a reference:

total energy expenditure = resting energy expenditure × activity factor × stress factor

  - For example: A 4-year-old male (15.9 kg), sedated and intubated with a closed head injury.

resting energy expenditure = (22.7 × 15.9) + 495 = 856 kcal/day

total energy expenditure = 856 × 1.0(activity factor) × 1.3(stress factor) = 1,113 kcal/day

Malnutrition

According to United Nations Children's Fund WHO-World Bank joint child malnutrition estimates (see Further Reading at the end of this chapter), 26% of all children under 5 years of age

are stunted, 16% are underweight, and 8% demonstrate wasting (90% are from Africa or Asia). "Protein-energy malnutrition" is an overarching term used to describe a deficiency of multiple nutrients.

Table 35-3. World Health Organization Equations for Estimating Resting Energy Expenditures*

	Resting Energy Expenditure (kcal/day)	
Age (years)	**Males**	**Females**
0–3	(60.9 × weight in kg) – 54	(61.0 × weight in kg) – 51
3–10	(22.7 × weight in kg) + 495	(22.5 × weight in kg) + 499
10–18	(17.5 × weight in kg) + 651	(12.2 × weight in kg) + 746

*Use in combination with an activity and stress factor to determine total energy expenditure.
Data source: World Health Organization. *Energy and Protein Requirements: Report of a Joint FAO/WHO/UNU Consultation*. Geneva, Switzerland: WHO; 1985. Technical Report 724.

Table 35-4. Effects of Activity and Stress Factors on Energy Requirements for Children

Type of Activity Factor	**Multiply REE By**
Nonambulatory (intubated, sedated)	1.0
Bed rest	1.1
Ambulatory	1.2–1.3
Type of Stress Factor	**Multiply REE By**
Starvation	0.7–0.9
Surgery	1.1–1.5
Sepsis	1.2–1.6
Closed head injury	1.3
Trauma	1.1–1.8
Growth failure	1.5–2.0
Burn	1.5–2.5
Cardiac failure	1.2–1.3

REE: resting energy expenditure

- Severe acute malnutrition (SAM) can present as follows:
  - Marasmus: severe deprivation of calories and protein characterized by severe wasting.
  - Kwashiorkor: the result of inadequate protein intake; characterized by bilateral dependent edema, flaking skin lesions, changes in hair color, abdominal bloating, and hepatomegaly.
  - Marasmic–kwashiorkor: a mixed form resulting in both wasting and bilateral pitting edema.
- Managing SAM
  - Therapeutic feeding programs are intensively managed dietary regimens with medical intervention (see references in the Further Reading section for detailed guidance) used to treat malnourished populations.
  - Military care providers practicing in remote or austere conditions are very likely to encounter individual patients with SAM.
  - The approach to these patients is distinct from nutritional support for critically ill or injured children.
  - Indications for therapeutic feeding programs:
    - MUAC less than 115 mm (for those ages 6–60 months; cutoffs for older age groups have not been established).
    - Weight for height z score less than 3 standard deviations below median (see WHO Child Growth Standards and the Identification of Severe Acute Malnutrition in Infants and Children in Further Reading at the end of this chapter).
    - Bilateral edema (kwashiorkor), regardless of weight, height, and MUAC measurement.
  - Individuals with SAM who have an appetite and no medical conditions requiring inpatient monitoring can be managed in an outpatient setting.
  - Ready-to-use therapeutic foods such as Plumpy'Nut (Nutriset, Normandy, France), MANA (Mana Nutrition, Matthews, NC), and BP-100 (GC Rieber, Bergen, Norway) are most commonly used and administered based on weight.

    - Children who fail to respond to ready-to-use therapeutic foods or who develop medical complications should be referred for inpatient care.
    - Humanitarian Daily Rations may also be provided in this setting, but are not a substitute for mass ration distribution and other relief actions. Each humanitarian daily ration offers complete daily nutrition with wide acceptance for diverse religious and dietary restrictions (National Stock Number: 8970013750516, The Wornick Company, McAllen, Texas). Detailed nutritional and logistic information about Humanitarian Daily Rations, as well as procurement information, is available through the Defense Logistics Agency (https://www.troopsupport.dla.mil/subs/rations/programs/hdr/hdrabt.asp).
- Refeeding syndrome
    - Severely malnourished patients experience loss of lean muscle mass, water, and minerals, with total-body depletion of phosphorus (although serum levels may remain normal).
    - Refeeding syndrome occurs when a malnourished patient is rapidly re-fed.
    - Carbohydrates trigger the release of insulin.
    - Intracellular glucose and phosphorous uptake and protein synthesis are enhanced.
    - Phosphorus-dependent metabolic functions decline, resulting in cardiac and neuromuscular dysfunction and acute ventilatory failure.
    - Potassium and magnesium stores may also become depleted, leading to further clinical complications.
    - Treatment
        - Refeeding syndrome can further be avoided when providing total parental nutrition (TPN) or tube feeding by starting delivery below the goal caloric intake and slowly increasing over several days while maintaining an appropriate ratio of calorie delivery from protein, carbohydrates, and fats.
        - During the initial phases of refeeding (first 3 days), electrolytes, including phosphorus, should be monitored frequently, ideally every 12 hours (if resources are available), and replaced as indicated.

    - Consider empiric phosphorus supplementation.
    - Anticipate constipation given reduced peristalsis.
  - If laboratory data is not available, observe the patient closely for physical signs of metabolic disturbances to guide therapy.
    - Hyperglycemia: polyuria, polydipsia, weakness, fatigue, and blurred vision.
    - Hypoglycemia: decreased consciousness, sweating, anxiety, shakiness, palpitations, weakness, hunger, faintness, headaches, tremor, and tachycardia.
    - Hypophosphatemia: weakness, respiratory failure, cardiac myopathy, seizures, and delirium.
    - Hypokalemia: cardiac arrhythmia, muscle weakness, nocturia, elevated blood pressure or hypotension, atonia, paraesthesia, and hyporeflexia.
    - Hypomagnesemia: seizure, muscle cramps, tetany, tremor, weakness, vertigo, dysphagia, and confusion.

Breast-Feeding

- Breast milk (orally or enterally) is always preferable to commercial formulas.
- Use of formula may undermine breast milk production and suggest to mothers that breast milk is inferior.
- Powdered formulas are frequently reconstituted with contaminated water.
- Breast milk should be given exclusively for the first 6 months of life and can routinely be given to children up to age 2 years or beyond.
- Managing SAM in children under 6 months of age should focus on establishing or reestablishing exclusive breast-feeding by the mother or other caregiver.
- If clean equipment is available to obtain pumped breast milk, additional calories and protein can be added to expressed milk if the volume is inadequate or the child's medical condition requires fluid restriction.
  - One scoop (8–9 g) of infant formula powder (20 cal/oz) added to 8 ounces of pumped breast milk (20 cal/oz) yields 24 calories per ounce.

- Carbohydrates from a clean source, such as granulated sugar (16 cal/tsp), can also be added to breast milk to increase caloric density. For example, 2 teaspoons of sugar added to 8 ounces of breast milk yields 24 cal/oz.

Tube Feeding

- When available, age-appropriate tube feedings should try to meet the goals outlined in Table 35-5.
- Standard adult formulas are acceptable in children over 1 year old and can be used if they are the only type available.
  - Protein content will be 1.5- to 2-fold that of pediatric products.
  - Intake above 4 grams of protein per kilogram per day should be avoided so as not to overwhelm renal urea excretion.
  - The higher osmolarity of adult formulas may also impact feeding tolerance and can be associated with increased stooling.
  - When using higher protein concentrations, ensuring adequate fluid intake is essential.
- High-protein formula may still not meet total caloric requirements. If additional calories are needed, they can be given using vegetable oil (100 kcal per 15 mL) and sugar (48 calories per 15 mL) or intravenous (IV) dextrose.
- The overall goal rate for enteral feedings will depend on the patient's caloric and fluid needs (Table 35-6). If the patient is on IV fluids, the volume should be adjusted accordingly.

Total Parenteral Nutrition

- Compared to pediatric formulations, premixed adult TPN solutions are higher in protein and some electrolytes, such as potassium (Table 35-7).
- When using premixed adult TPN, calculate the maximum volume of solution to avoid excessive volume intake, then adjust with additional dextrose 50% to meet estimated calorie needs.
- If no central access is available, give as partial parenteral nutrition; however, the osmolarity should be less than 900 osmoles per liter, and dextrose concentration should be no higher than 12.5%.

Table 35-5. Nutritional Needs (Enteral and Oral) in Infants and Children

			Distribution of kcals		
Age (yr)	Calories (per kg)	Protein (g/kg)	Fat	Protein	Carbohydrate
0–1	80–120	2.5–3.5	35%–45%	8%–15%	45%–65%
1–10	60–90	2.0–2.5	30%–35%	10%–25%	45%–65%
11–18	30–75	1.5–2.0	25%–30%	12%–25%	45%–65%

Table 35-6. Guidelines for Initiating and Advancing Continuous Enteral Feeding

Age (yr)	Initial Infusion	Incremental Advances
0–1	1–2 mL/kg/h	10–20 mL/kg/day
1–6	1 mL/kg/h	10 mL/kg every 2–8 h
> 7	10–25 mL/h	20–25 mL every 2–8 h

*Hourly infusion increases incrementally until goal calories are achieved.

Table 35-7. Parenteral Electrolyte Needs

	Infants and Toddlers	Children	Adolescents
Sodium	2–4 mEq/kg	2–4 mEq/kg	60–150 mEq
Potassium	2–4 mEq/kg	2–4 mEq/kg	70–180 mEq
Chloride	2–4 mEq/kg	2–4 mEq/kg	60–150 mEq
Magnesium (125 mg/mEq)	0.25–1 mEq/kg	0.25–1 mEq/kg	8–32 mEq
Calcium (20 mg/mEq)	0.45–4 mEq/kg	0.45–3.15 mEq/kg	10–40 mEq
Phosphorus (31 mg/mmol)	0.5–2 mmol/kg	0.5–2 mmol/kg	9–30 mmol/kg

- Maintain a balanced distribution of calories from protein, carbohydrate, and fat (see Table 35-4, use the lower range of recommended protein) to maintain nutrient efficiency and to minimize hepatic damage from TPN.

Specific Nutrient Needs in Certain Conditions

- Burns, open wounds, gunshot wounds, and fragment injuries will require higher calorie intake, higher protein intake, and supplementation with vitamin C and zinc, if available (otherwise use a standard multivitamin-mineral supplement).
- Ventilated, sedated, or paralyzed patients need lower calorie intake; however, they have standard protein needs (see Table 35-5).
- For sepsis, give midrange calories and protein.
- If the patient is febrile, give increased calories and protein.
- Intake needs for patients with amputation should be based on actual weight measurements, when available. Otherwise, estimate needs based on adjusted ideal body weight.

Micronutrients

The following micronutrients significantly impact morbidity and mortality in food-insecure populations worldwide. Specific and proven interventions are feasible for US military medical systems to implement on small scales and support on a larger scale.

Vitamin A

- Signs and symptoms of vitamin A deficiency include xerophthalmia, night blindness, corneal and conjunctival xerosis, Bitot's spots (greyish foamy patches on the conjunctiva), corneal ulcers, and keratomalacia.
- Treatment and prevention
  - Early recognition and treatment can prevent irreversible loss of sight and other ophthalmologic complications and reduce measles-related mortality. All children diagnosed with measles should receive vitamin A supplementation at the time of diagnosis, 24 hours later, and again in 4 to 6 weeks.

- In nutritionally at-risk populations, empiric, oral, twice yearly vitamin A supplementation is recommended (Table 35-8; see *Periodic, Large Oral Doses of Vitamin A for the Prevention of Vitamin A Deficiency and Xerophthalmia: A Summary of Experiences*, in Further Reading at the end of this chapter). This is an especially important adjunct for controlling or preventing outbreaks of measles.

Table 35-8. Vitamin A Dosing for Deficiency Prevention

Age	Vitamin A Dose	Frequency
< 6 months	50,000 IU	Single dose
6–12 months (or under 8 kg)	100,000 IU	Every 4–6 months
1–5 years (or over 8 kg)	200,000 IU	Every 4–6 months

Iron

- Signs and symptoms of deficiency include fatigue, weight loss, thin or spoon-shaped nails, and pallor of skin, conjunctiva, nail beds, and palms.
- Complete blood count, if available, frequently shows a microcytic anemia.
- Treatment and prevention consists of the following:
  - Improve access to iron-rich or fortified foods based on local availability.
  - The WHO recommends periodic, empiric, mass drug administration targeting soil-transmitted helminth infections (albendazole, typically every 6 months) and schistosomiasis (praziquantel) to improve nutritional status, prevent anemia, and reduce overall morbidity (see Prevention and control of schistosomiasis and soil-transmitted helminthiasis, in Further Reading at the end of this chapter). Sleeping under insecticide-treated nets may also reduce anemia due to malaria.
  - Provide iron supplements. Education and follow-up care are key to increasing compliance and preventing toxicity from accidental overdose; however, these are difficult to provide

in a deployed setting and are compounded by language barriers. Avoid providing iron supplements during the initial phase of treatment for SAM, as it increases the rate of complications. Iron supplementation may increase morbidity from malaria in settings with poor access to therapy.

Zinc

- Zinc deficiency is widespread in developing countries. Most cases are asymptomatic, though deficiency impacts immune function and wound healing.
- Treatment and prevention are as follows.
  - For cases of diarrhea, zinc supplementation lasting 10 to 14 days reduces severity, duration, and recurrence of diarrhea.
  - Zinc acetate should be given as a supplement and not part of a multivitamin.
  - Dosing (in elemental form; 10–14-day course):
    - Infants younger than 6 months old: 10 mg/day.
    - Children older than 6 months: 20 mg/day.
  - Zinc supplements may now be available in the Central Command formulary as zinc sulfate 220 mg tablets, and as IV multitrace 4 for use with TPN Multitrace-4 Pediatric (trace elements injection 4, USP; American Regent, Inc, Shirley, NY). **Note**: The US Food and Drug Administration indication for Multitrace-4 is as a supplement to IV solutions given for TPN. Each milliliter provides:
    - zinc: 1 mg,
    - copper: 0.1 mg,
    - manganese: 25 μg, and
    - chromium: 1 μg.
  - Zinc supplements are also commercially available under the trade name Orazinc 110 (Mericon Industries, Inc, Peoria, IL). Each tablet provides 25 mg of elemental zinc. If using Orazinc 110, recommended dosages comparable to WHO guidelines are as follows:
    - Infants between 2 to 6 months: half a tablet or 12.5 mg elemental zinc once daily for 14 days.
    - Children older than 6 months to 5 years old: one tablet or 25 mg elemental zinc, once daily for 14 days.
- See Table 35-9 for specific signs of other nutritional deficiencies.

Table 35-9. Signs of Specific Nutrient Deficiencies

Nutrient	Deficiency Symptoms
Protein	Kwashiorkor, weakness, lethargy, edema, ascites, fatty liver, dermatitis, depigmented hair, alopecia, decubitus ulcers, moon face, muscle wasting, growth failure, hypotension, cheilosis, stomatitis, delayed wound healing
Protein/Energy	Marasmus; dry, dull hair; drawn-in cheeks; carious teeth; ascites; diarrhea; weakness; irritability; increased appetite; muscle wasting; growth failure; other vitamin deficiencies
Fat/EFAs	Xerosis; flaking; scaly skin; dermatitis; follicular hyperkeratosis; dry, dull hair
Vitamin A	Eggshell nails, night blindness, dermatitis, taste changes, xerosis, keratomalacia
Vitamin C	Decubitus ulcers, perifolliculitis, petechiae, bleeding gums, swollen gums, stomatitis, bone pain, dry or rough pigmented skin, poor wound healing, anemia
Vitamin D	Rickets, bowed legs, prone to fractures, restlessness, frequent crying, sweating, muscular atony, weakness, scoliosis, back pain, bone pain, spinal changes
Calcium	Weight loss, muscle weakness, bone pain, skeletal deformities
Vitamin B_{12}	Megaloblastic anemia, scarlet tongue, fatigue, weight loss, jaundice, oral mucosa ulcerations, dementia, sensory loss, yellow skin pallor, hypertrophy, gait sensory ataxia
Iron	Fatigue, weight loss, glossitis, stomatitis, tachycardia, tachypnea, thin or spoon-shaped nails
Zinc	Delayed wound healing, alopecia, night blindness, taste changes, decubitus ulcers, delayed wound healing, dermatitis, erythema, xerosis
Iodine	Goiter, outer third of eyebrow missing
Thiamine	Edema, weakness, irritability, burning feet, pruritus, nausea, vomiting, anorexia, muscle wasting, muscle tenderness and cramps, beriberi, photophobia, confusion

(**Table 35-9** *continues*)

(**Table 35-9** *continued*)

Niacin	Pellagra, dermatitis, diarrhea, dementia, red/scarlet tongue, erythema, depression, irritability, stomatitis, glossitis, cheilosis, hyperpigmentation
Folic acid	Megaloblastic anemia, skin pallor, stomatitis, scarlet tongue, glossitis, sensory loss, oral mucosa ulcerations
Riboflavin	Flaking, scaly dermatitis, conjunctivitis, magenta tongue, stomatitis, glossitis, cheilosis, hypertrophy

EFA: essential fatty acid

Further Reading

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Chapter 36

Nursing Assessment

Pediatric Growth and Development

Child development is organized into developmental stages, and communication with children should be appropriate to their stage of development. Interpreters should be used to explain care and treatment to parents or caregivers and children. If an interpreter is not available, a picture board may be used as a communication tool. Keep in mind that published US pediatric growth curves may be less useful in developing countries.

Developmental Stages

- **Infancy: birth to 12 months of age**
  - First month of life (neonatal period) is differentiated from subsequent months due to major physiologic adjustments.
  - This is a time of rapid motor, cognitive, and social development.
  - Children in infancy are dependent on caregivers.
  - These children respond to pain by crying and withdrawing.
  - Milestones approximation
    - 2 months: head control.
    - 4 months: arms and chest control.
    - 6 months: sitting.
    - 8 months: crawling.
    - 10 months: standing supported/cruising.
    - 12 months: walking, few words, self-feeding.
  - Children in this stage can make eye contact, orient preferentially to faces, and track brightly colored objects.
  - These children have an open anterior fontanelle until around 16 months.
  - Nursing considerations
    - Assess activity, movement of extremities, eye contact, and tracking to voice or objects.

- Irritability along with high-pitched, shrill, or weak cry is a concerning finding.
- Weakness, flaccidity, or an unresponsive infant is indicative of clinical deterioration.

- **Early childhood: 1 to 6 years of age**
  - **Toddler: 1 to 3 years of age**
    - Developmental characteristics include:
      - upright, to walking, to language development, to activity and discovery;
      - toilet training begins (bowel then bladder, daytime then nighttime);
      - ability to eat table foods;
      - fear of abandonment and separation anxiety; and
      - denial or saying "no" (common toddler behavior).
    - Toddlers are very ritualistic; disruption in their routine leads to a feeling of loss of control.
    - Nursing considerations
      - To minimize separation anxiety and fear, keep a parent or caregiver with the child or hold the child during assessment or interventions.
      - Lack of anxiety during separation from a parent or caregiver may indicate clinical deterioration.
      - Children at this age are resistant to being touched, separated from their caregivers, having their clothing removed, and donning masks (eg, oxygen).
      - Children at this age may believe that injury and illness are forms of punishment.
  - **Preschool: 3 to 6 years of age**
    - These children typically:
      - are toilet trained;
      - are entering into school;
      - talk in full sentences, think concretely;
      - exhibit more subtle responses to stress (eg, loss of appetite or sleep) than toddlers;
      - have active imaginations that may lead to exaggeration and fear, or to fantasies that may take over; and
      - are curious about equipment and tasks.
    - Nursing considerations: Children this age
      - may worry over body integrity (eg, wonder if a body part under a cast is actually missing);

        - have increased awareness and fear related to pain, death, blood, or permanent injury;
        - think concretely and interpret what they hear literally; and
        - believe that injury and illness are their own fault and view them as punishment.
- **Middle childhood: 6 to 11 or 12 years of age**
    - Key characteristics of this period
        - A critical period of self-concept.
        - Characterized by development of peer relationships.
        - Children are concerned about privacy and are self-conscious when undergoing physical examinations.
        - Children may be anxious about death.
        - Illness or injury affects the child's sense of self-worth or achievement.
        - Children are capable of cooperating with procedures and answer questions about health.
- **Later childhood: 12 to 19 years of age**
    - Prepubertal: 10 to 13 years
    - Adolescence: 13 to approximately 18 years
        - This is a period of rapid biological and personality maturation, with the onset of puberty and development of secondary sexual characteristics.
        - Adolescents fear loss of control and enforced dependence.
        - Children this age believe that nothing bad can happen to them.
    - Nursing considerations for middle and later childhood:
        - Vital signs are similar to those of adults.
        - Children this age are concerned with privacy and modesty.

Communicating With Children

- Explain procedures to children and their parents; plan on having to repeat explanations.
- Talk in a quiet, gentle tone.
- Be reassuring to children and parents.
- Provide a security object.
- Keep your hands visible.
- Use appropriate terminology.

- Assign the child a task if possible (eg, "keep your eyes on the purple cow in your bed").
- Explain monitoring noises.
- Use the child's name.

Admission Tips and Preparation

- Establish weight in kilograms with a scale or estimate weight using the Broselow tape (see the inside back cover).
- Develop a binder or computer file with emergency medication calculations of the most commonly used medications, and divide doses into 5-kg increments.
- A precalculated emergency medication sheet should be posted at each child's bedside.

Online weight-based emergency medication calculators are available (see http://www.globalrph.com/acls-pediatric.htm, or refer to the Broselow tape for emergency medication dosing).

Obtaining Vital Signs

- Refer to Chapter 1, Basic Approach to Pediatric Trauma, Table 1-1 for normal vital sign ranges by age.
- A satisfactory pulse rate can be obtained radially in children over 2 years of age. Use the brachial or apical pulse method for children less than 2 years of age.
- If time and situation permit, listen to pulse for at least 1 minute to detect potential irregularities.
- The preferred site for noninvasive blood pressure (BP) measurement is the right upper arm. Other sites for BP measurement include the left arm, thighs, and calf.
- Temperature can be obtained by axillary method from birth to over 5 years of age. Axillary temperature measurement frequently underestimates core temperature.
- If a definitive (core) reading is needed, obtain a rectal temperature in infants to 5 years. Care should be taken when obtaining rectal temperatures in neonates. Avoid taking rectal temperatures in neutropenic patients. Oral temperature measurement can be used in older children.
- Fever is a temperature greater than 38°C; hypothermia is a temperature less than 36°C.

Respiratory/Airway

- Refer to the comprehensive equipment table in Appendix C for appropriate equipment sizes for airway adjuncts, such as masks for bag-valve mask ventilation, oral pharyngeal airway, nasopharyngeal airway and endotracheal tubes (ETTs), and suction catheters.
- Intubation supplies needed include:
  - A monitor to evaluate heart rate, BP, and respiratory rate (cycle BP every 5 minutes during procedure).
  - A spare ETT and stylets (appropriate size and one size smaller).
  - Functional intravenous (IV) access.
  - Emergency medications.
  - Functioning Yankauer catheter and suction.
  - Bag-valve mask ventilation with appropriately sized mask, attached to flowing oxygen.
  - End tidal carbon dioxide detector.
  - Ventilator.
- Nursing tips for care of the intubated patient
  - Pediatric ETTs are often flimsy in children and can occlude. Consider using a stiffer tube as a stent outside the primary tube.
  - Pediatric ETTs need to be suctioned at least every 2 to 3 hours.
  - Always have an extra tube at the bedside for emergencies.
  - Prevent ventilator-associated conditions (eg, pneumonia).
    - Elevate the head of the bed to 30 degrees, unless contraindicated.
    - Assess and document the position of the ETT every 4 hours and during transport, and with any change in the patient's position.
    - Use waterproof (cloth) tape to secure tubes (because of oral secretions). DO NOT use paper tape.

Cardiovascular/Intravenous Access

- Refer to Chapter 1, Basic Approach to Pediatric Trauma, Table 1-1 for age-specific BP and pulse measurements.

- Assess capillary refill time for adequate perfusion. Normal capillary refill time in children should be 2 seconds or less.
- Supplies for IV access
  - Alcohol prep pads, tourniquet, pore tape, Tegaderm (3M Co, St Paul, MN).
  - IV catheters; sizes 24 and 22 are the most commonly used in children.
  - Butterfly needles can be used in emergency situations; however, they must be adequately secured with pore tape with constant provider monitoring of the site.
  - Intraosseous (IO) placement should be considered immediately in critically ill children in need of urgent access. See Chapter 3, Vascular Access, for guidance beyond routine peripheral IV access.
- Nursing tips
  - Forms of restraint for IV placement include swaddling (infants), and mummy restraint with a sheet for small children.
  - Have at least 2 or 3 people help hold a toddler down for blood work or IV placement.
  - Make sure the involved extremity is well restrained before starting.
  - IO access requires careful securing and monitoring of the insertion site and constant evaluation by provider.
  - Stabilize the IV extremity with an armboard.
  - Armboards may be constructed by using two tongue blades or by cutting down larger armboards used for adults. Pad the board with 4×4 gauze and monitor the extremity for potential skin breakdown at pressure points.
  - Normal saline is the fluid of choice for resuscitation. Typical bolus amount is 10 to 20 mL/kg.
    - Push fluids in using syringes during resuscitation; infusion pumps take too long.
    - For fluid boluses in infants, use a 20 to 60 mL syringe with a 3-way stopcock to a normal saline bag. This method can be used to deliver rapid boluses.
  - For maintenance fluids, to avoid unintentional delivery of excess fluid, program a load of only 2 hours of volume to be infused into the pump.

- Frequently reassess IV site.
- Document all fluid given, including flushes, in the intake section of the nursing flow sheet.
- Although not recommended, blood draws may be obtained from IV sites. Aspirating from 24-gauge IVs placed in smaller veins may result in the loss of the IV.
- Blood may also be collected via heel stick.
- Pediatric tubes are recommended for laboratory samples to minimize blood loss.
- A hand-held analyzer, such as an iStat (Abbott Laboratories, Abbott Park, IL), is recommended to handle small blood volumes.
- Ensure the blood amount taken is documented in the "output" section of the nursing flow sheet.

Neurological

- Monitor for altered mental status using the Glascow Coma Scale score (with infant modifications, if appropriate). See Chapter 1, Basic Approach to Pediatric Trauma, Table 1-3 for the Glasgow Coma Scale, including infant modifications.
- Record Glasgow Coma Scale score regularly and notify physician if there is deterioration.
- Early signs and symptoms of increased intracranial pressure (ICP)
  - Infant: change in mental status, lethargy, poor feeding, bulging fontanelle.
  - Child: change in mental status, severe acute headache, seizure activity.
- Nursing care of increased ICP in infant and child
  - Keep the head of the bed elevated 30 to 45 degrees.
  - Maintain the head and neck in the midline position.
  - Maintain normothermia.
- ICP monitoring**:** See Figures 36-1–36-3. Also see Chapter 13, Neurosurgery, for more information on the utility of ventriculostomy catheters for both management and monitoring of ICP.



Fig 36-1. Transducer stopcock set "open to drain."

Pain

- Pain is often undertreated in children.
- Response to painful stimuli is individually based on prior experiences and cultural beliefs.

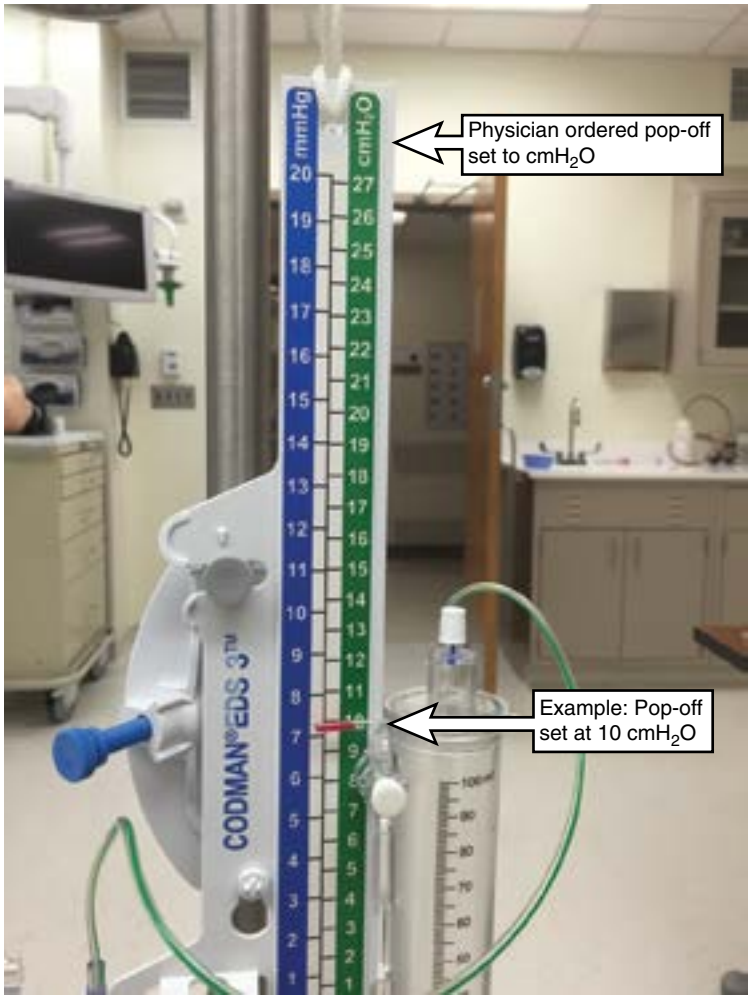


Fig 36-2. Transducer stopcock set "off to drain" to transduce accurate intracranial pressure.

- Children 7 years of age and above typically use the 0-to-10 pain scale. Other scales include the FLACC (Face, Legs, Activity, Cry, Consolability) scale (see Merkel, et al, in Further Reading) and the Wong-Baker FACES scale (see Baker C, Wong D, in Further Reading).

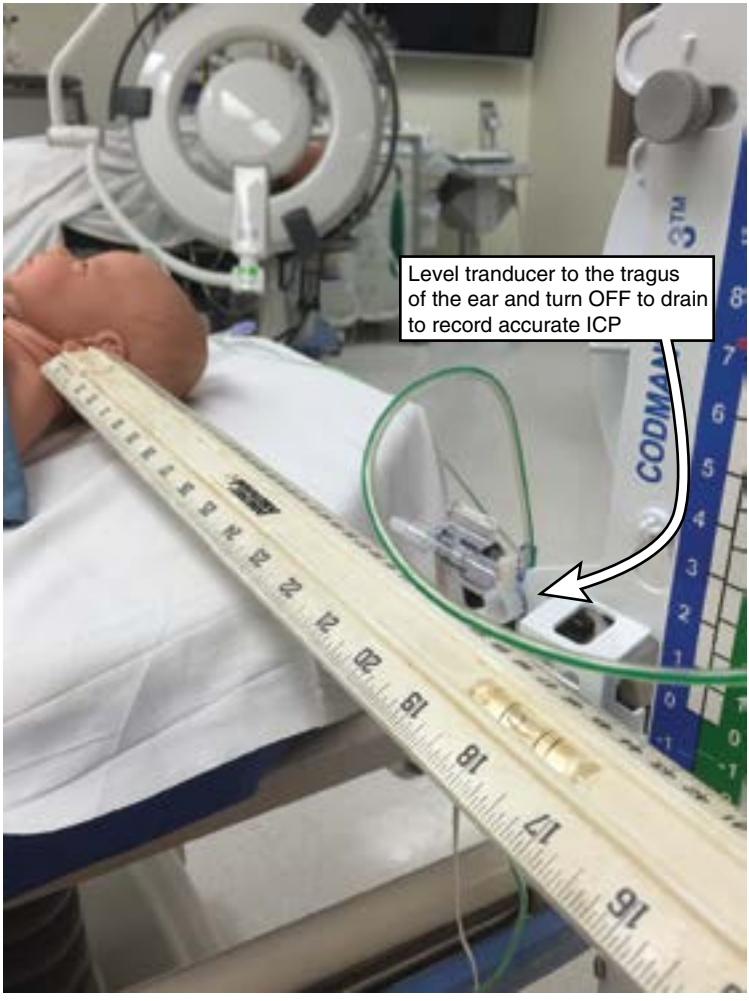


Fig 36-3. Level to tragus of the ear to transduce accurate intracranial pressure.

- A simple pain management approach is an "around-the-clock" baseline analgesic (eg, acetaminophen or ibuprofen) with supplemental, as-needed narcotics.

Gastrointestinal and Genitourinary

- Evaluate the child's nutritional status and have culturally specific foods on hand to promote nutrition.
- Have electrolyte-containing oral solutions on hand, such as Pedialyte (Abbott Laboratories, Abbott Park, IL).
- Have nipples, 60-mL graduated feeders, and pacifiers in stock.
- Order specialized nipples, such as a pigeon nipple, if there is high incidence of cleft palate in the area of operation.

Tubes and Drains

- Refer to the comprehensive pediatric equipment sizing table in Appendix C of this book for approximate sizes according to weight.
- Size 5 and 8 Fr feeding tubes can also be used as Foley catheters in infants less than 6 months old.
  - Connect tubing to a urimeter by attaching it to a syringe without a plunger.
  - An inline burette can also be used as a urine collection device.
- Foley catheters can get clogged; therefore, irrigation may be necessary if a sudden drop in urine output is noticed.
- To measure small amounts of output, consider hooking to an upright Lukens trap with suction.
- Nasogastric (NG) tube placement: measure the tube from the child's nose to earlobe to xiphoid process. Secure the tube to the side of the child's face with Tegaderm or Medipore (3M Co, St Paul, MN) tape. Confirm placement with radiograph.
- Tube feeding may be necessary for nutritional rehabilitation. It can be useful in the acute setting of a child with dehydration. It is also useful for enteral drip fluid and electrolyte replacement when IV placement is impossible.
  - Usually the feeding tube is placed nasogastrically, but transpyloric feeds can be used in children if severe vomiting continues with an NG tube.
  - To encourage transpyloric passage, allow slack on the tube and add metoclopramide (0.1–0.2 mg/kg PO/IV).
  - Appropriate tube size depends on the patient's age; see comprehensive pediatric equipment sizing table in Appendix C for guidance.

- The tube should be soft and changed periodically (approximately every 4 to 6 wk) if used long term.
- Feeding with a continuous drip is helpful in vomiting patients because more calories can be delivered with less vomiting.
- In the case of a transpyloric tube, continuous feeding is imperative; bolus feeds can only be given via the NG route.
- The appropriate fluids through an NG tube are formulas or electrolyte solution, not pureed foods.

Pediatric Medication Administration Tips

- Take a confident, positive approach; be kind but assertive.
- Allow the child some control by offering appropriate choices (eg, allow the child to choose which arm to use for an injection or the flavor of an oral drug chaser; never give the child a choice when none exists).
- Be truthful about the pain and discomfort associated with the procedure.
- Compare the expected sensation with something the child has likely experienced before (eg, a pinch or a pinprick).
- When explaining how long a procedure will take, remember that children generally do not fully understand the concept of time until approximately 7 to 8 years of age; use terms the child can understand (eg, "by the time you count to 3, it will be over").
- Children tend to take language literally; avoid using imprecise and potentially frightening jargon.
- Because needles and syringes can produce anxiety, keep them out of the child's view until you're ready to administer the medication.
- Oral administration
  - Check the child's gag reflex and ability to maintain airway in the presence of fluids; assess for nausea and vomiting.
  - A liquid dosage form ensures a more accurate dose for children; use liquid dosage whenever it is available (exceptions include phenytoin, carbamazepine, and isoniazid).
  - If only tablets are available, crush and mix them with compatible syrup or food. Do not crush extended release

or sustained release tablets. Crushing may reduce the effectiveness of some drugs. Check with a pharmacist or consult a drug manual before crushing and mixing medications.

- For liquid-soluble medications, a small syringe may be used. Remove the plunger from the syringe and place the tablet inside. Replace the plunger and use it to crush the pill. Then 1 or 2 mL of water, saline, or other liquid may be used to dissolve the medication.
- To administer oral drugs to infants:
  - Raise the infant's head to prevent aspiration.
  - Gently press down on the infant's chin with your thumb to open the infant's mouth.
  - Administer the dose.
    - Syringe: place the tip of the syringe in the pocket between the patient's cheek and gum. This prevents the child from using the tongue to spit out the medication. Administer slowly and steadily to prevent aspiration.
    - Nipple: place medication in a rubber nipple and allow the infant to suck the contents.
    - Never mix medications into a baby's bottle (if the child does not finish the entire bottle, the correct dosage will not be ingested; also, some formulas interfere with the absorption of some drugs).
    - For safety, never refer to a drug as "candy" or a "treat," even if it has a pleasant taste.

- NG route: check for residuals if giving enteral feedings that interfere with drug absorption.
- Rectal route
  - Be aware of the special significance of this part of the body to children.
  - Toddlers in toilet training will resist the rectal route.
  - Older children perceive this as an invasion of privacy and may react with embarrassment, anger, or hostility.
  - To reduce a child's anxiety, explain the procedure and reassure the child that it will not hurt.
  - After administering the suppository, hold the child's buttocks together for a few minutes to prevent expulsion.

- Concurrent critical illness may impair absorption.

- IV infusion
  - To reduce pain at the injection site, offer to use topical anesthetic preparations (eg, lidocaine/prilocaine) with occlusive dressing 30 to 60 minutes prior to the IV access attempt.
  - Although there is a greater incidence of infiltration and phlebitis in children, the IV route is the most effective to deliver medications during critical illness.
  - Use smaller flushes of 2 to 3 mL after each medication. Adult "standard" flush volume is too much for infants and children.
  - Check the compatibility of the solution. Ensure IV medications, flushes, and parenteral nutritional fluids infused in the same IV line are physically and chemically compatible.
  - In infants (especially neonates), hyperosmolar drugs must be diluted to prevent radical fluid shifts that may cause intracerebral hemorrhage.
- Intramuscular (IM) injection
  - Do not use lidocaine as a diluent for drugs needing reconstitution; doing so places the patient at risk for local anesthetic toxicity.
  - Reconstitute medication in the highest concentration possible to avoid having to administer two separate injections to give the entire dose.
  - The optimum site for IM injection depends on the child's age:
    - Less than 3 years old: vastus lateralus (lateral thigh) muscle.
    - Older than 3 years: gluteus muscle or ventrogluteal area.
    - Appropriate needle size depends on the child's age and muscle mass.
      - In young infants, a ⅝-inch needle is usually used.
      - Children or thin, debilitated adolescents may require a 1-inch or smaller (⅝-in.) needle.
      - For most children and adolescents, use a 1-inch or 1.5-inch needle, respectively.

        - Needle gauge is determined by the viscosity of the drug formulation. A 19-gauge needle is used for viscous drugs (eg, penicillin G procaine). A 21-gauge needle is used for aqueous formulations (eg, penicillin G).
        - To avoid unnecessary tissue damage, use the shortest length and highest gauge needle possible.
        - The optimum amount of drug to administer via an IM site varies with the child's age, size, and health.
        - Usual maximum volume for IM administration:
          Neonate: 0.5 mL
          Child: 1–2 mL
          Adult: 2–3 mL
        - Rotate sites.
- IO route: recall that any medication that may be given IV may also be given IO.
- Subcutaneous (SQ) injection
  - Infants and children have less SQ fat than adults.
  - The SQ injection procedure is similar to IM injection, but uses shorter needles and volume should be limited to 1.5 mL or less.
    - Use a 25-gauge to 27.5-gauge needle.
    - For infants and small children 3 years old and younger, use a $\frac{3}{8}$-inch or $\frac{1}{2}$-inch needle.
    - For larger children, use a $\frac{5}{8}$-inch needle. Obese children and adolescents may require a 1-inch needle.
- Inhalants
  - Correct administration depends on the child's cooperation.
  - If a nebulizer is to be used to deliver medication, the child needs to wear the mask at all times during drug delivery. Nebulized medicines with a blow-by technique lose 90% of drug delivery.
  - Inhalants can be used in children as young as 3 months old if an appropriate spacer (valved holding chamber with mask) is available.
  - Clean the spacer with warm water and mild soap every week to minimize bacterial contamination; do not rinse soap from the inside of the holding chamber; the soap film acts as a surfactant and reduces static charge so that medication particles do not adhere to the sides of the chamber.

- Prime the spacer with several actuations of the metered-dose inhaler prior to use.
- Use a different spacer for each child (do not share spacers).
- Common spacer instructions (spacer instructions may vary; read package insert for specific instructions):
  - Shake canister well before (5 seconds) each puff.
  - Properly assemble canister-spacer.
  - Inhale and exhale slowly (if possible).
  - Place spacer mouthpiece between lips (or mask that covers the child's nose and mouth completely).
  - Press canister down one time.
  - Inhale slowly (if a whistle sound is heard, patient is inhaling too fast).
  - Take spacer out of mouth and close mouth.
  - Hold breath for 10 seconds, then exhale slowly.
  - If unable to hold breath for 10 seconds, exhale and inhale into spacer up to 10 times.

Further Reading

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Chapter 37

Behavioral Healthcare of Children in Austere Environments

Introduction

Psychological trauma is frequently overlooked as caregivers tend to focus on treating a physical injury or illness. The emotional and cognitive sequelae must be treated as well as the physical complications of injury, and both can be quite severe. Healthcare providers should consider and vigorously address psychological sequelae as soon as a patient arrives for treatment, and they must integrate behavioral healthcare into the patient's plan of care. This chapter will highlight several useful principles for the care of injured (and psychologically traumatized) children in a deployed medical-surgical setting and provide ways for a busy provider taking care of injured children to intervene psychiatrically to improve both compliance and outcomes.

General Principles

Principle 1: All "Psychiatric" Issues Are Organic Until Proven Otherwise

- Clinicians are obligated to perform a full medical evaluation, including physical examination and laboratory and diagnostic studies, before making a psychiatric diagnosis.
- In the face of new onset psychiatric symptoms, always rule out traumatic injuries, intracranial pathology, sepsis, metabolic syndromes, toxic exposures, and delirium (waxing and waning consciousness) before resorting to a psychiatric diagnosis.

Principle 2: Behavioral Health Concerns Need to Be Addressed With the Same Care as Other Medical Concerns

- A bio-psycho-social history, including specific (targetable) symptoms, should be documented. In complex situations, the histories provided may be limited, unreliable, or impacted by the lack of a safe environment. It is important to get a sense of the remote past and the context (what happened around the onset of symptoms) as well as more immediate events. Focus on the specifics of current symptoms—the more specific the better—including:
  - time course, including specific event and symptom evolution;
  - severity (what makes symptoms worse or better?); and
  - other bio-psycho-social narrative components:
    - Biological: Is there a family history of psychiatric problems?
    - Temperamental: What kind of temperament does the child have? Anxious? Securely attached?
    - Developmental: Has the child met normal milestones? Does the child make eye contact? Is speech normal? Does the child exhibit any unusual behaviors?
    - Event-based: Has the child lost attachment figures? Has the child relocated? Has the child sustained abuse? Did the child witness traumatic events (eg, people being injured, explosions)?
- Historians may be unreliable because they:
  - may be traumatized (not able to manage the experiences);
  - may not have been present but are willing to conjecture;
  - don't want to provide the history (for reasons that may not be obvious to the provider);
  - may purposefully falsify the story, either consciously or unconsciously; or
  - may be confronting unsettling realities and their own unsavory choices.
- In certain environments, stating reality can be highly dangerous. The risks of ongoing physical danger to both the patient and the historian should always be considered when analyzing the history obtained and planning for the future.

Principle 3: Work in the Cultural Context in Which You Find Yourself

- Clinicians should prepare themselves by learning the local traditions and then budgeting time and effort to perform them.
  - Medical "scrubs" and white coats may be off-putting and anxiety provoking.
  - Western understanding of professionalism may not be understood or accepted, an individual's "character" may be of greater importance.
  - If time allows, providers should establish a "therapeutic relationship" with their patients.
    - Spend time and energy establishing a personal relationship with patients, parents, and elders.
    - Know and acknowledge local customs, respect attitudes, and make efforts to reach out in warm and generous ways.
- Patients do not necessarily share the same worldview as their caregivers and may even disagree with the most basic goals for treatment.
- Assume that foreign patients and their families may not entirely trust clinicians and do not understand medical treatments or procedures.
- To understand the local culture, a list of customs should be reviewed and considered, including:
  - Is it a male-dominated culture? How are women to be treated, both publicly and privately?
  - Who should be addressed first in a group?
  - How should one introduce oneself?
  - What's the best way to conduct a physical examination so as not to offend?
  - What are the prevailing religious beliefs and how do they relate to medical care?
  - What are the local experiences with the healthcare facility and providers?
- In many cultures, sharing food or a beverage, such as tea or coffee, engenders trust.
  - Allow the senior person to eat or drink first.
  - This custom may be essential to working together.
  - Don't talk about the medical "work" until the repast is over.

Principle 4: Communication Is Key

- Clinicians should use reliable methods of communication, including drawings, to exchange information with the patient and responsible adults.
- Translation is surprisingly unreliable.
  - Clinicians expect a translator to provide a simple linguistic translation; however, translators generally make what they deem appropriate cultural interventions. As a result, clinicians are frequently dumbfounded at the reactions to recommended interventions.
  - Ensure translators are an active part of the working team. Knowing and influencing the translator's attitudes can have dramatic impact on treatment.
- Interventions involving drawing, writing, and pictures (eg, using white boards and models) can be invaluable tools; however, keep in mind that graphic displays or pictures may be offensive in some cultures.
  - Many cultures are dominated by superstitions and strongly held beliefs (eg, belief in evil spirits, the role of "elixirs," illness or injury as punishment for sins or "hexes"), and these can quickly creep into medical discussions. Enlisting a local holy or medical person may prove useful.
  - The process of educating patients includes understanding and appreciating local beliefs as well as communicating the clinician's goals for treatment.
- Remember that patients and their families may be illiterate.

Principle 5: There Are Often Several "Patients" to Be Treated

- Ensure patients and caregivers understand the point and nature of treatment procedures.
- Ensure patients and responsible adults have a cognitive understanding of the medical problems and the treatment in the context of the cognitive, developmental, and educational level of the audience.
- Pediatric patients have limited cognitive abilities and, depending on their developmental age, use more or less "magical" thinking, and primitive associations.

- Lay out simple explanations. Focus on making sense of events and what needs to be done, and create a meaningful narrative to explain the healing process.
- Provide enough detail for the patient and adults to understand the basics, and no more.
- If children feel safe and have a relationship with the provider, they may ask further questions to titrate their own anxiety. If they don't ask, they may not want to know more.
- Children often have frightening fantasies about things they don't fully understand. Be cognizant of evolving phobias and anxiety.
- Positive reassurance, accompanied by simple mechanical explanations using metaphors from the local environment (eg, how streams work for explaining fluids, or how plants or animals grow), is best.
- Providing "toys" and visuals can help clarify otherwise confusing explanations and may also provide amusing distractions (eg, glove "balloons" or plastic syringe "water toys") and create a warmer and "safer" environment.

- The other "patients" to be considered are the parents or responsible adults, who are less likely to be open, transparent, or trusting and are often more fearful than the child.
  - Talk to parents or responsible adults without the child present to explore their fears *before* administering a treatment.
  - Even when time is of the essence, exploring the adult's (sometimes irrational) understanding of the injury, treatment, and outcome fears will prove extremely beneficial for treatment compliance and outcome.
  - Designating an alternative provider to liaise with the parent may save time, but it potentially splits the authority and can appear disrespectful.

Principle 6: Provide a Safe Environment

- Psychological safety is a key goal. Physical comfort and a psychologically nourishing environment facilitate compliance and speedy medical recovery.

- Anxiety is the most frequent behavioral health problem and the final common pathway for all conditions.
  - Anxiety is the psychological equivalent of pain and always needs to be considered and treated.
  - Anxiety and stress result from physical hardship and injury, changes in conditions, novel experiences, and an environment that results in sleep deprivation, disturbing recollections, and future worries. Stress is ubiquitous and can be toxic.
  - Treatment should focus on reducing stress and anxiety, which includes managing physical pain (see Chapter 2, Anesthesia).
  - Ensure patients are physically comfortable and that the environment is stable and predictable.
  - Cultural supports (pictures, religious items, etc) and close friends and family in attendance are highly valuable.
  - Employing families to minister to patients is generally culturally consistent, helps the family and patient connect with the medical team, ensures some continuity of care after discharge, and ensures that the patient receives warmth and human contact.

Principle 7: Encourage Verbalization

- Much therapeutic benefit comes from the process of talking, which can limit the danger of irrational fears. Distinguishing between fears and wishes, thoughts and words, and actions and reality can be quite useful.
- Children frequently have a hard time differentiating and verbalizing the nature of their distress. They can protect themselves in primitive ways. For example, as they try to manage their internal experiences, they "act out" their distress through physical symptoms (somatic complaints) or unruly behaviors (refusal, agitation, etc).
- The goal of treatment is to allow patients to communicate their internal thoughts and learn to deal with their distress in appropriate, acceptable, and healthy ways.
  - Encourage verbalization and play.
  - Ensuring loved ones are available, along with toys and props, allows healthy expression of anxiety.

  - Once a certain level of trust is established, young or "shy" children may be unexpectedly willing to share thoughts, feelings, and fears.
  - Be aware that both the parent and the child can be retraumatized by recollections or expressed concerns.
  - It is up to the clinician to slow the child down, help titrate the intensity, and keep the patient from becoming overwhelmed.
- Adolescents will often maintain a distance or even become hostile to a clinician or unfamiliar caretaker. This hostility psychologically defends the vulnerable adolescent from intense feelings or dangers. Adolescents can (understandably) lash out in very destructive ways.

Principle 8: Discharge Planning Should Always Be a Part of the Initial Treatment Plan

- While providing safety, clinicians must also balance the warmth and care of the treatment environment with clear expectations for the family about the end of treatment.
- Managing the end of treatment and what will happen after discharge can be challenging. Medical follow-up may be difficult to arrange, and how a patient and his/her family will obtain even the most basic needs may be unclear. If the child is an orphan, the family's home is threatened, or the family members are outcasts, the end of treatment at a Western treatment facility will only be the beginning of their travails.
  - Outside conditions often act as a disincentive to the goal of a speedy recovery.
  - Patients and their families can become needy and pathologically dependent on the medical environment to protect themselves from a hostile and dangerous outside environment.
  - Enslavement, prostitution, and forced military draft are common in austere environments and threaten catastrophic changes for patients who are pending discharge.
- As discharge approaches, expect clinical setbacks and appreciate they may be manifestations of the patient's (and the family's) anxiety about the future.

- At the beginning of the treatment process, create a clear expectation for the end of treatment (and of the finite nature of the care). Ensure those responsible have a clear expectation of what should happen after treatment is over.

Treatment

Phases

- Generally, there are three phases to treatment of new onset symptoms, particularly posttraumatic conditions:
  - Acute: In the immediate aftermath of a precipitating event (and within the first few hours), the focus of treatment is to provide safety and security and to decrease hyperarousal and shock.
  - Medium term: The first few days after an event, when the situation is still "raw" and cognitively "in play," stabilization and symptom relief are indicated. Clinicians should focus simply on:
    - managing hyperarousal symptoms, helping patients feel safe and secure in a comfortable environment;
    - providing reassurance, minimizing reminders of the event, and normalizing symptoms; and
    - ensuring patients (and family) are able to sleep, eat, and regain normal daily routines.
  - Long term: Beyond the acute aftermath, the goals of treatment are to establish a stable environment and manage symptoms, providing behavioral health treatments (eg, cognitive behavioral, exposure, etc) and medications.
    - Careful consideration should be given entering into a long-term therapeutic relationship with local foreign patients.
    - Many medications will not be available in the local health system.
    - The impending departure of care providers may provoke anxiety and feelings of abandonment in patients or their families.

Therapeutic Modalities

- A calm, safe environment is a powerful tool. A low-stimulus environment that provides physical comfort; a clean, temperate shelter; food; a predictable schedule; rest; and the safety of loved ones can stabilize the situation and prevent further traumatization.
- Talking and play therapies using the principle of metaphor are also effective. Difficult or traumatic experiences can be processed through the brain by representation, either with words, play, or games. This indirect means allows the patient to control the level of arousal associated with the experiences and make sense of them through narrative in a way that is not emotionally overwhelming.
  - Play allows the experiences to be put in a larger context that "makes sense" without the experience fundamentally challenging the patient's understanding of the world.
  - With increasing age and sophistication, patients may be able to benefit more from cognitive therapies (as opposed to more "imaginative" play therapies).
- There are virtually no psychotropic medications approved by the US Food and Drug Administration for small children, and only a few for adolescents. Psychotropic medications are frequently used "off-label" in children and are derivative of their uses in adults in smaller doses.
  - Psychotropics should generally be thought of as adjuncts to other therapies. They should be used for treatment of targeted symptoms with clear understanding of their effects, side effects, dosing, benefits, and toxicities. Psychotropics are potentially quite dangerous. A clinician should be educated about psychotropic use and dosing in pediatric patients or seek expert psychiatric consultation before prescribing unfamiliar psychotropic medications.
  - The medications most commonly used are as follows:
    - Anxiety and depressive symptoms: selective serotonin reuptake inhibitors (eg, fluoxetine, sertraline, citalopram, etc).
    - Behavioral disorders, including agitation, aggression, and mood lability: "atypical" antipsychotic medications (eg, risperidone, aripiprazole, olanzapine, etc).

    - Inattention and hyperactivity symptoms: stimulants (methylphenidate, dextroamphetamine, etc).
    - Mood lability, aggression, and bipolar illness: mood stabilizers (eg, valproic acid, carbamazepine, topiramate, etc).
    - Mood lability, aggression, and anxiety: consider sedation with benzodiazepines (eg, lorazepam, clonazepam).
    - Other assorted medications may also be useful, such as:
        - clonidine for aggression, tics, and Tourette syndrome;
        - anticholinergics (diphenhydramine and benztropine) for insomnia and acute agitation;
        - hydroxyzine (antihistamine) for anxiety; and
        - melatonin and/or zolpidem for insomnia.
- Restraints: Isolation and restraints **should be a last resort** and only used to maintain the safety of the patient and the treatment team. The goal of isolation is to place the patient in a safer environment where he/she cannot endanger anyone.
    - Isolation and "threatening" physical force can be highly alarming for patients and their families.
    - Offer medications to a highly agitated patient before physically restraining the patient.
    - When dealing with agitated small children, a provider can wrap themselves around the child and use their weight gently to contain the child, applying "reassuring control" and preventing the child from hurting themselves or others.
    - If the patient is older or larger, leather restraints may be required. Staff should be trained and organized into a "take down team," ideally consisting of seven members: a leader, a person to manage each limb, one to manage the head, and one to administer medications. Any take down should be protocol-driven with established triggers and be preceded by a brief discussion by the team away from the patient.
    - Every effort should be made to de-escalate dangerous behaviors using a calm and quiet tone of voice; restraints are only used to maintain safety.
    - If absolutely necessary, deliberate overwhelming force can be used to take control of each limb and the patient's head, taking care to avoid injury.

- If the patient has refused oral medications, an intravenous (IV) or intramuscular (IM) cocktail can be administered to a restrained patient.
  - A sedating cocktail of an antipsychotic, typical (eg, haloperidol) or atypical (eg, ziprasidone); a short-acting benzodiazepine (eg, lorazepam); and an anticholinergic (eg, diphenhydramine) can be administered: orally, IV, or IM.
    - These require different preparations, so it is important **before** a take-down to have oral preparations ready (to offer the patient before the take-down) and IM/IV preparations ready for **after** the patient has been restrained.
    - These medications are highly sedating; be prepared for the patient to become somnolent quickly and remain so for a period of time.
- Restraints carefully placed on each limb can secure the patient to a bed or stretcher and should be maintained for as brief a time as possible (less than 2 hours).
- An attendant should be within an arm's reach at all times and should regularly (every 15 minutes) check the restraints to ensure they are not too tight, that they allow for adequate perfusion, and that extremities are warm, with good capillary refill.
- Once a patient is asleep, restraints should be carefully removed one limb at a time.
- Administering restraints can be a highly emotional experience. Afterward, separately debrief witnesses (such as family members), the restraint team, and the patient.

Psychiatric Conditions

- Given the difficulties of translation and different cultural norms between Western medical providers and patients in austere or hostile environments, there is little use focusing on specific diagnoses as described in the *Diagnostic and Statistical Manual of Mental Disorders*. The focus should be on the approach to managing common symptom complexes.

- Psychiatric syndromes tend to cluster. For example, anxiety disorders that may cluster together include posttraumatic stress, generalized anxiety, obsessive-compulsive disorder, panic, and specific phobias, as well as depression, grief, and bipolar illnesses. These conditions should be considered and treated.
- PsySTART, a behavioral health triage system (http://www.cdms.uci.edu/PsySTART-cdms02142012.pdf) identifies patients at risk for trauma-related sequelae. It includes specific questions about:
  - death or injury of people close to the child,
  - separation from loved ones,
  - damage and destruction to the child's home, and
  - thoughts of harm (to self or others).
- Once determined to be at risk, a patient may receive preventive psychological services, if they are available.

Anxiety

- Anxiety is the most common psychiatric symptom that will confront a clinician in a deployed or austere environment.
- Anxiety severity can range from mild nervousness to full-blown catatonia. It is a rare psychiatric emergency that can present in two dangerous forms: immobile or agitated.
  - Immobile catatonia manifests as unresponsiveness and rigidity.
    - Patients can cease to eat or function autonomically (including urinating and defecating).
    - Patients can become dehydrated and develop rhabdomyolysis or kidney failure.
    - It is imperative that the clinician monitor the patient's vital signs, get venous access, and provide fluids, as well as treat the anxiety.
  - In contrast, agitated catatonia is accompanied by wild and uncontrollable agitation, including flailing and aggressive behaviors. The uncontrolled movement can result in physical trauma, reduced intake, dehydration, hypoglycemia, and other metabolic abnormalities.
  - In both cases, the treatment of choice is IV benzodiazepines.

- Causes of anxiety often involve traumatic events that frighten or threaten a person's "bodily integrity" (eg, rape, injury, or witnessed death); the loss of a loved one or destruction of familiar objects (home, environment); or stimuli that overwhelm a person's senses (eg, loud noises, shock, gore, destruction). A flood of neurotransmitters and neuroendocrine factors lead to hyperarousal and the formation of intense memories.
- Anxiety can present as or be accompanied by:
  - specific phobias;
  - "numbing," or cognitive withdrawal from the circumstances (mutism or catatonia);
  - hyperactivity and behavioral acting out (including attention deficit disorder-type behaviors);
  - behavioral regression (including bedwetting and loss of behavioral milestones);
  - compulsive or repetitive rumination about, or "acting out" of, actions related to the event;
  - severe agitation, crying, hysteria, disorganized behaviors, and simple nonresponsiveness to the environment; and
  - symptoms of obsessive-compulsive disorder, such as a rigid need to have things said, done, or arranged in very precise and exact ways (from an outsider's point of view, this appears irrational or strange).
- Acute stress reaction may also occur after a traumatic event. Psychiatric interventions should be environmental first (decrease stimulus in the environment, provide quiet, use soft light, ensure comfortable seating, provide food and soft "transitional" objects [ie, comforting soft toy], and maintain access to trusted adults).
  - The goal when treating acute stress reaction is to decrease hyperarousal.
  - If possible, clinicians should avoid direct questioning and history gathering.
  - Acute medications, such as anticholinergics, beta blockers, and sedatives, may be considered. **However**, anticholinergics and sedatives (such as benzodiazepines) can have a paradoxical effect in children (disinhibit rather than calm them).

  - Low-dose antipsychotic medications (such as risperidone) can be effective adjuncts.
  - If a patient is overwhelmed with anxiety, more extreme measures may be necessary to prevent self-harm.
  - Providing a quiet room or administering medications such as antipsychotics may be required (eg, risperidone sublingual or ziprasidone IM).
  - Dosing regimens according to weight and agent should be carefully consulted (side effects of atypicals can include seizures, QTC prolongation, extra pyramidal symptoms, tardive dyskinesia, neuroleptic malignant syndrome, akathisia, and acute dystonia).
- Posttraumatic anxiety reactions can be accompanied by symptoms of psychosis, such as hearing the voices of or seeing the dead or wounded. These symptoms should be considered part of the anxiety process and not of an undiagnosed psychotic process (eg, schizophrenia), which is very rare in prepubescent children.
- Anxiety over the loss of an attachment figure can make it difficult to treat children.
  - Western providers often think of this as a variant of "school avoidance." It is characterized by children having intense anxiety if they are required to be separated from their mothers or a member of their family.
  - This type of anxiety should be managed the same way as other anxiety disorders.
  - This disorder is the result of both the child's anxieties and those the caretaker "transmitted" to the child. Treat both the child and the context (including the person he/she is afraid of losing).
- Medium and long-term treatment of anxiety requires assessment of developmental needs, screening for the psychological effects of trauma, and effective communication.
  - After a thorough evaluation of the patient and his/her family, commence targeted treatment of medical conditions, including pain and delirium.

- Explore posttraumatic stress disorder symptoms (hyperarousal, numbing, avoidance, reliving the events). Avoid situations, people, or objects associated with the traumatic event, which can induce panic and extreme acting out, intense memories, flashbacks, and nightmares.
- Be aware of grief reactions, depression, and other disorders.
- Generally, talk therapy is indicated first, sometimes accompanied by medication (antidepressants or anxiolytics).

Disordered Sleep

- Sleep is an essential aspect of psychological healing and overall well-being. Ensure patients are able to sleep, are physically comfortable, and are not being awakened unnecessarily or waking themselves.
- Sleep disorders can be characterized by:
  - early, mid-, and late-cycle insomnias (ie, trouble falling asleep or staying asleep, or waking up early);
  - nighttime activity (eg, night terrors or somnambulism); and
  - fear of sleeping (as a result of fear of further trauma or of their nightmares).
- Although a child may naturally suffer from night terrors, he/she may also be suffering from posttraumatic nightmares, which can resemble night terrors and include intense nighttime physical activity (restlessness), vocalizations, somnambulism, and evidence of intense distress.
- Many patients wake themselves with panic symptoms (racing heart, shortness of breath, diaphoresis, and sense of impending doom) and then have trouble going back to sleep.
- A normal fear of the dark can become exaggerated to the point that a child does not want to go to sleep and is afraid to do so. This needs to be addressed vigorously with interventions to ensure that the patient (and his/her family attendants) are physically comfortable, feel safe (have a person present, perhaps in the same bed), and, as a last resort, have medications that ensure sleep initiation (often anticholinergics, as long as they do not result in paradoxical arousal).
- For initial insomnia, ensuring the environment is conducive to sleep (low lighting, no noise) can be augmented with sleep aids, such as diphenhydramine, melatonin receptor agonists, and non-benzodiazepine hypnotics.

- Low-dose antipsychotic medication (eg, risperidone or quetiapine) may ultimately be required to help the patient become drowsy and to decrease the intense ruminations and fear reactions that impair the capacity to stay asleep. Clonidine may also be useful.
- In adults, prazosin has proven effective for treating posttraumatic nightmares (it helps patients fall and stay asleep); however, there are currently no studies on the use of prazosin for nightmares in children.

Grief and Depression

- Symptoms of grief and depression are often not the same in children and adolescents as in adults, though children may exhibit some similar symptoms, such as becoming tearful and withdrawn or having decreased energy and appetite. Instead, children are often clingy, easily agitated, and complain of somatic problems, such as headaches, stomachaches, and nonspecific pains.
- Children can be withdrawn or they can become oppositional, angry, or "bad," breaking the rules and refusing to act according to specified norms.

Antisocial Behaviors, Oppositionality, and Aggression

- Inappropriate behaviors can be difficult to manage in a clinic or a hospital. The roots of bad behavior can be far-ranging, from poor parenting to maladaptive reactions to acute stress.
- Fear may cause a child to be aggressive.
- Compulsively acting out traumatic events is a way of turning a passive experience (being a victim) into an active one (being the aggressor).
- First and foremost, maintain the safety of other patients, staff, and the child or adolescent who is behaving badly. Act aggressively to prevent harm, including assault, bullying, threatening, and stealing (food, possessions, or medications). Once safety has been adequately established, implement a well-delineated treatment plan to modify the aberrant behaviors. Depending on the developmental age of the child:
  - A reward/punishment system can be put into place.

  - Medications, such as clonidine, low-dose risperidone, or ariprazole, can be used to manage aggression and outbursts.
- Other diagnoses can be ruled out or treated, such as toxins and ingestions, intracranial pathology (eg, traumatic brain injury), and metabolic causes.

Mass Casualty Events and Disasters

- One of the most profound effects a disaster can have on a local community is psychological. A disaster may best be understood as a terror-inducing event. The site of a mass casualty (MASCAL) event or a natural disaster is generally chaotic. For the clinician, it can be difficult to distinguish the patients with medical complications from the psychiatric casualties.
- Local medical facilities can be flooded with patients experiencing panic symptoms, such as shortness of breath, racing heart, diaphoresis, and a sense of impending doom. Symptoms can mimic nerve agent or other toxic exposures.
- It is important during MASCAL events for a clinician to step back from a traditional role and consider the broader perspective. Clinicians must be savvy to the larger implications of the event and tailor their approach to the nature and breadth of the disaster.
- A standard approach may be to use PsySTART or refer to the *Psychological First Aid Field Operations Guide* for psychological triage and first aid.
- Many topics for consideration are covered in this book (see Chapter 42, Children in Disasters).
- The most effective way to manage anxiety and decrease the resulting behavioral health complications of a MASCAL event is to deal with the noninjured population.
- An effective public affairs office that can communicate information from the epicenter of the event to locals, family, and the media can minimize the problems associated with the aftermath of a MASCAL event (overloaded highways, access to the MASCAL site, overwhelmed phone and cellular lines, etc).

- For onsite disasters (eg, a plane crash or building collapse), establishing protocols for aid workers to have an area of respite (including food and beverage points) and "transition times" (for those coming on and off shift) to provide effective information for their replacements can be invaluable in helping workers debrief and process their experiences.
- Behavioral health workers can play effective roles in triaging and debriefing site victims; however, they may also be effective in helping at gathering points to assess and debrief aid workers and behind barriers to mingle with family and friends trying to reach the MASCAL site.
- Often, the role of behavioral health provider is not as culturally welcome as other more innocuous roles. Some behavioral health providers may wish to introduce themselves as "security workers," which allows them more entrée and creates a greater sense of safety.

Psychological Well-Being of Providers

- Injured children evoke more stress in staff than any other patients. Team resilience can be strengthened with special staff training and support for caretakers to reduce secondary traumatization and burnout.
- Self-monitoring for apathy, moodiness, overwork, insomnia, and demoralization, and aiding colleagues with such symptoms, is important in prevention.
- Self-care entails maintaining physical wellness; sustaining a balance of emotions, interests, and work; maintaining restorative personal relationships; knowing one's own physical and emotional limits; and getting help when it is needed.

Conclusion

It is all too easy for a busy healthcare worker in an austere environment to focus solely on medical complaints, unintentionally neglecting the larger context and the impact of a patient's subjective experience, which frequently determines the patient's engagement in treatment. Healthcare providers must acknowledge that psychiatric symptoms exist and feel comfortable proceeding with treatment despite the limitations

of the environment. Providers must also remember to manage their own anxiety and psychological stress so they can provide the best possible care to their patients.

Online Resources

- The American Academy of Child and Adolescent Psychiatry has a large database of multilanguage handouts, practice parameters, and recommendations.
  - American Academy of Child and Adolescent Psychiatry. Facts for Families website. http://www.aacap.org/AACAP/Families_and_Youth/Facts_for_Families/Home.aspx. Accessed January 30, 2015.
- The National Child Traumatic Stress Network offers resources for education and learning, including Psychological First Aid Online.
  - National Child Traumatic Stress Network. Learning Center for Child and Adolescent Trauma website. http://learn.nctsn.org/course/. Accessed January 30, 2015.
- The goal of the Nebraska Disaster Behavioral Health Project is to mitigate the psychosocial consequences of terrorism and disaster. It brings together many resources for disaster response.
  - University of Nebraska Public Policy Central. Nebraska Disaster Behavioral Health Project website. http://www.disastermh.nebraska.edu/. Accessed January 30, 2015.
- The Inter-Agency Standing Committee coordinates humanitarian assistance for the United Nations and many nongovernmental organizations.
  - Inter-Agency Standing Committee website. http://www.humanitarianinfo.org/iasc/. Accessed January 30, 2015.
- The Uniformed Services University of the Health Sciences Center for the Study of Traumatic Stress (accessed January 30, 2015) has an educational campaign to facilitate communication about war injuries between healthcare providers and families.
  - The Uniformed Services University of the Health Sciences Department of Psychiatry. Center for the Study of Traumatic Stress website. http://www.centerforthestudyoftraumaticstress.org. Accessed January 30, 2015.

- The Uniformed Services University of the Health Sciences. Courage to Care, Courage to Talk . . . About War Injuries website. http://www.couragetotalk.org. Accessed January 30, 2015.

- PsySTART is a behavioral health triage system that identifies patients at risk for trauma-related sequelae.
  - Schreiber M. The PsySTART Rapid Mental Health Triage and Incident Management System. http://www.cdms.uci.edu/PsySTART-cdms02142012.pdf. Accessed January 30, 2015.

Further Reading

1. American Psychiatric Association. *Diagnostic and Statistical Manual of Mental Disorders*. 5th ed. Arlington, VA: American Psychiatric Publishing; 2013.

2. National Child Traumatic Stress Network and National Center for PTSD. *Psychological First Aid Field Operations Guide*. Rockville, MD: US Department of Health and Human Services; 2006. http://www.nctsn.org/sites/default/files/pfa/english/1-psyfirstaid_final_complete_manual.pdf.

Chapter 38

Pharmacotherapeutics

Factors Affecting Pharmacokinetics

Children are not simply small adults. As they grow, children's bodies undergo changes in absorption, distribution, metabolism, and excretion; all of which affect the pharmacokinetics of drugs. Many of the drugs and dosages used in infants and children are not specifically approved by the US Food and Drug Administration (FDA) for those indications in those patient populations. Some of the drugs and dosages recommended in this text are not FDA approved, but are widely accepted as appropriate.

Absorption

- Drug absorption is influenced by:
  - age;
  - physiologic condition;
  - drug dosage, form, and physical properties; and
  - interactions with concurrent medications and foods.
- Absorption of oral drugs mostly takes place in the small intestine, where pH ranges from 4 to 8.
  - The pH of neonatal gastric fluid is neutral to slightly acidic, but becomes more acidic as the infant matures.
    - The pH of neonatal gastric fluid usually reaches adult values by 2 years of age, but may take until the child is up to 6 years of age.
    - This higher gastric pH affects the absorption of some drugs (eg, phenytoin, phenobarbital, ampicillin, nafcillin, and penicillin G).
  - Neonates have erratic, prolonged gastric emptying times and intestinal transit times, which leads to increased absorption. Gastric emptying time reaches adult values by 6 to 8 months of age.

  - Most oral medications have been found to be safely and efficiently tolerated and absorbed by nonseptic neonates.
  - Older children have faster gastric emptying and transit time, which leads to decreased absorption.
  - During the first few months of life, neonates have immature biliary function that results in a decreased amount of bile salts and decreased absorption of lipid-soluble drugs (eg, vitamin E).
  - Concurrent administration of infant formulas or milk products temporarily increases pH and may impede absorption of acidic drugs (eg, furosemide and phenobarbital).
  - Critical illness often shunts blood from the gut to the heart and brain, effectively decreasing the gut's ability to absorb medication.
  - Neonates, infants, and young children should receive oral medications on an empty stomach unless the pharmacokinetics for the specific medication will be affected by the presence of food and change in pH.
- Absorption of parenteral drugs
  - Neonates and young infants have small skeletal muscle mass and variable blood flow; therefore, absorption of drugs administered via the intramuscular and subcutaneous routes may be unpredictable, especially in the context of shock or poor perfusion.
  - Properties of some medications influence intramuscular absorption (eg, phenobarbital [rapid], diazepam [slow]).
- Absorption of topical drugs
  - Neonates and infants have enhanced absorption of topical drugs due to the relative thinness and the high water concentration of their skin.
  - Neonates and infants possess a high proportion of body surface area (BSA) to total body mass, which can lead to systemic, toxic, and adverse reactions to topical agents (eg, isopropyl alcohol, steroid ointments, and hexachlorophene soaps).

Distribution

- Developmental changes in body composition affect drug distribution.

- Premature infants: body fluid equals up to 85% of total body weight.
- Term neonates: body fluid equals 55% to 70% of total body weight.
- During the first 12 months after birth, total body fluid decreases dramatically, then gradually decreases to adult proportions by 12 years of age.
  - Body fluid equals 50% to 55% of an adult's total body weight.
  - Extracellular fluid is 40% of a neonate's weight (as opposed to 20% of adult's weight).

- Solubility in lipids versus water affects distribution of drugs and dosages.
  - A higher proportion of fluid to body weight greatly enhances the distribution of water-soluble drugs.
  - The low ratio of fat to muscle in children limits the distribution of fat-soluble drugs.
  - Plasma protein binding affects distribution; only free (unbound) drugs, can exert a pharmacological effect.
    - The affinity of plasma proteins to bind with drugs is reduced in neonates.
    - Bilirubin and free fatty acids compete with drugs for binding sites on plasma proteins and further reduce the protein-binding abilities of drugs in neonates; sulfonamides, salicylates, penicillins, and furosemide displace bilirubin from plasma proteins.
    - Children less than 3 months old have significantly less albumin and α-1-acid glycoprotein than adults; drugs that bind primarily to these proteins must be administered in reduced doses.
    - Drug binding to plasma protein reaches adult levels by approximately 12 months of age.
  - Immaturity of the blood–brain barrier in neonates results in greater drug penetration of cerebrospinal fluid (eg, aminoglycosides).

Metabolism

- Most drugs are metabolized in the liver.
  - Some enzymes reach adult levels at a few months of age, while others may take years.

  - Neonates have a large liver (40% of body mass versus 2% in adults); therefore, they have a relatively larger surface area for metabolism.
  - A neonate's immature liver and enzyme system may impede metabolism. The ability of a child to metabolize many drugs may not be developed fully until 12 to 15 months of age.
- Older infants and children metabolize some drugs more rapidly than adults (eg, carbamazepine, oxcarbazepine, quinidine, phenytoin) and may require larger doses to achieve a therapeutic effect.
- Enzymatic functions mature over time.
  - Glucuronidation (a process the liver uses to eliminate and detoxify drugs) is not sufficiently developed until 1 month of age.
  - Standard pediatric dosages of some drugs may produce adverse or toxic reactions in neonates (eg, chloramphenicol).
  - Intrauterine exposure to drugs may induce early development of hepatic enzymes, which will result in increased capacity to metabolize drugs.
  - Concurrent drug use can produce interactions that may stimulate or reduce liver enzyme activity (eg, phenobarbital can increase metabolism of phenytoin, requiring an increased dose of phenytoin).

Excretion

- Most drugs and metabolites are excreted in the urine.
- Glomerular filtration rate reaches adult levels by 12 months of age in most full-term infants; premature infants will take longer to reach adult levels. Renal tubular secretion mechanisms become fully functional after glomerular filtration rate has reached adult levels.
- Maturity of the renal system and presence of renal disease can affect drug dosage requirements.
- Renal function is much more developed in full-term neonates than in premature infants.
- Inadequate renal excretion results in drug accumulation and possible toxicity unless doses are reduced, dosing interval is increased, or both, depending on the medication.

Administering Drugs to Children

- General rules
  - Pediatric medication doses should not be extrapolated from adult doses.
  - There are no standardized units for pediatric drug dosing.
    - Most drug dosages are expressed in mg/kg/*dose* or mg/kg/*day*; some references list the units in "mg/kg/d." The "d" may stand for dose or day. Confirm with source.
    - Some dosages are calculated using BSA in units expressed as mg/m^2/dose or mg/m^2/day. BSA for children and adults (in m^2) may be calculated using the following:

$$\sqrt{\frac{\text{Ht (cm)} \times \text{Wt (kg)}}{3{,}600}}$$

  - Many drug regimens require modification because of renal insufficiency or failure; usually the dose is decreased, the dosing interval is changed, or both.
    - See Chapter 33, Pediatric Nephrology, to calculate the creatinine clearance (ClCr) using the Schwartz Formula. This formula may not provide an accurate estimation of ClCr for infants less than 6 months of age or for patients with severe starvation or muscle wasting.
    - The change in medication regimen with renal insufficiency depends on the drug and extent of impairment. Common cut-off points for regimen modification are ClCr less than 70, less than 50, less than 25, and less than 10 mL/minute/1.732.
      - The lower the ClCr, the more severe the renal insufficiency.
      - Consult a pharmacist or pediatric drug reference for specific regimen changes.
      - Reevaluate dosages at regular intervals to ensure proper adjustment as renal function changes.
  - Ensure that the BSA or body weight dosage is age-appropriate.
  - Many liquid medication preparations will settle and require shaking before use to equally redistribute drug in suspension.

- When calculating amounts per kilogram, **do not exceed the maximum adult dosage** or maximum daily dosing.
- **Always** check dosing in an appropriate, published, pediatric drug reference (eg, *The Harriet Lane Handbook* or *NeoFax* [http://sites.truvenhealth.com/neofax/; Truven Health Analytics, Ann Arbor, Michigan] for neonates, and always double-check all computations).

Emergency Pediatric Drug Therapy

- Emergency pediatric drug therapy requires quick, accurate dosage calculations and proper administration techniques (Table 38-1).
- Refer to the Broselow tapes and PALS cards inside the covers of this book to assist with the dosing and sequence of medications for the various resuscitation algorithms.
- Many drugs used for pediatric resuscitation are the same as those used for adults, but with different dosages or concentrations based on weight or BSA.
- Emergency drug sheets must be filled out individually and kept at the child's bedside.
- Medication administered via peripheral vascular access (followed by a flush), a central line, or intraosseous access is equally efficacious.
- The endotracheal route may be used to administer epinephrine, atropine, and lidocaine. However, endotracheal administration of drugs is no longer recommended by the Neonatal Resuscitation Program (see *Textbook of Neonatal Resuscitation* in Further Reading).
  - Usually the dose is 1.5- to 10-fold that for the intravenous route.
  - Follow drug administration with a 5-cc flush of normal saline to aid in drug delivery to the peripheral airways.

Table 38-1. Drugs Used During Pediatric Cardiopulmonary Arrests

Drug (generic)	Class	Indications	Dose	Comments
Epinephrine	Catecholamine with α & β effects	• Cardiac arrest; symptomatic bradycardia; PEA, VF, VT • Use infusion postarrest if intermittent boluses failed to restore perfusing cardiac rhythm	• Initial: 0.01 mg/kg IV/IO; 0.10 mg/kg via ET • Repeat every 3–5 min during resuscitation	• The volume given is always 0.10 mL/kg (ie, 0.10 mL of 1:10,000 solution = 0.01 mg/kg) • For ET delivery (0.10 mL of 1:1,000 solution = 0.10 mg/kg) • Follow with 5-cc NS flush • Can cause local tissue necrosis
Atropine	Parasympatholytic agent	Symptomatic bradycardia refractory to optimal airway management	• 0.02 mg/kg IV, IO, ETT • Min dose: 0.1 mg Max dose: child = 0.5 mg adolescent = 1 mg	• CO is HR-dependent • Symptomatic bradycardia MUST be treated • Doses < minimum recommend may cause bradycardia in infants

(**Table 38-1** *continues*)

Table 38-1 *continued*

Adenosine	Antiarrhythmic agent	Reentrant SVT	• Initial: 0.1 mg/kg rapid IV/IO bolus • Repeat dose: 0.2 mg/kg • Max single dose: 12 mg	• Short half-life; bolus rapidly and as centrally as possible • Follow immediately with 5–10-cc NS flush via 3-way stopcock • Be alert for possible asthma exacerbation
Sodium Bicarbonate	Alkalinizing agent	Documented severe metabolic acidosis due to prolonged arrest; hyperkalemia; TCA overdose	• 1 mEq/kg IV or IO • May empirically dose 0.5 mEq/L every 10 min over 1–2 min if ABG results not available	Infuse slowly and only if ventilation is adequate • May decrease ionized Ca^{++} levels • May cause Na^{+} and H_2O overload
Glucose		Hypoglycemia	• 0.5–1 g/kg IV (2–4 mL/kg $D_{25}W$; 5–10 mL/kg $D_{10}W$) • Max concentration: $D_{25}W$	• Hypertonic glucose ($D_{25}W$ or $D_{50}W$) may harden peripheral veins if it extravasates • Do not exceed 12.5% Dextrose in neonates

(**Table 38-1** *continues*)

Table 38-1 *continued*

Calcium chloride	Calcium salt	Hypocalcemia, hyperkalemia	• 0.2 mL/kg of elemental calcium (20 mg/kg) • Repeat after 10 min prn if ionized calcium deficiency persists	• Infuse no faster than 100 mg/min. May induce bradycardia or asystole, especially if patient is also on digoxin • Extravasation can cause chemical burn or sclerosis of peripheral veins
Naloxone	Narcotic agonist	Narcotic poisoning	**Birth–5 y (≤ 20 kg)**: 0.1 mg/kg IV/ETT **> 5 y (≥ 20 kg)**: 0.4–2 mg/dose IV/ETT Continuous infusion: 0.04–0.16 mg/kg/h, titrated to effect	• Rare side effects usually related to abrupt narcotic reversal • Administer with caution immediately after birth to infants of addicted mothers to avoid abrupt withdrawal and seizures in infant
Magnesium sulfate	Antiarrhythmic agent; electrolyte	Hypomagnesemia torsades de pointes	25–50 mg/kg IV/IO (max dose: 2g/dose)	• Monitor serum Mg^{++} level • Use with caution in patients also on digoxin (can lead to heart block)

(**Table 38-1** *continues*)

Table 38-1 *continued*

Lidocaine	Antiarrhythmic agent	Ventricular dysrhythmias	**Loading**: 1 mg/kg **Infusion**: 20–50 μg/kg/min (concentration: 120 mg lidocaine/100 mL D_5W)	• Toxic levels can cause myocardial, circulatory, and/or CNS depression • Metabolized by the liver

ABG: arterial blood gas
CNS: central nervous system
CO: cardiac output
D_5W: dextrose 5% in water
$D_{10}W$: dextrose 10% in water
$D_{25}W$: dextrose 25% in water
$D_{50}W$: dextrose 50% in water
ET: endotracheal
ETT: endotracheal tube
HR: heart rate
IO: intraosseous
IV: intravenous
PEA: pulseless electrical activity
PRN: pro re nata (as needed)
NS: normal saline
SVT: supraventricular tachycardia
TCA: tricyclic antidepressant
VF: ventricular fibrillation
VT: ventricular tachycardia

Further Reading

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2. Taketomo CT, Hodding JH, Kraus DM. *Pediatric Dosage Handbook: Including Neonatal Dosing, Drug Administration, & Extemporaneous Preparations*. 16th ed. Hudson, OH: American Pharmaceutical Association-Lexicomp; 2009.

3. Custer JW, Rau RE, Lee CK. *The Harriet Lane Handbook: Mobile Medicine Series, Expert Consult: Online and Print*. 18th ed. Philadelphia, PA: Mosby; 2008.

4. Mosteller RD. Simplified calculation of body surface area. *N Engl J Med*. 1987;317(17):1098 (Letter).

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7. Engorn B, Flerlage J. *The Harriet Lane Handbook: A Manual for Pediatric House Officers*. 20th ed. Philadelphia, PA: Saunders/Elsevier; 2014.

8. Kattwinkel J, ed. *Textbook of Neonatal Resuscitation*. 6th ed. Elk Grove Village, IL: American Academy of Pediatrics; 2011.

Chapter 39

Bites and Stings

Introduction

Arthropod, insect, and snake envenomation are common medical problems but may be complex due to the variety of animals and the nature of exposures involved. Mortality rates in humans from most venom exposures are low.

There are specific problems with envenomation in children. Smaller children do worse with envenomation than adults because the snake or arthropod injects the same amount of venom into a much smaller host. Children are also poor historians, so a reliable story of the incident may be difficult to obtain. Unnecessary procedures, such as incision and suction over wounds and tourniquets, increase morbidity.

History

- Focus on the following when taking a history after envenomation:
  - timing of the event,
  - location of the bite or sting,
  - nature of what happened, and
  - whether or not spiders, snakes, or scorpions have been seen in the area or home.
- General symptoms of envenomation include pain, swelling, headache, and nausea. More severe symptoms may include necrosis, shock, and respiratory arrest.
- Physical examination
  - Examine the patient's entire body, paying special attention to the hands, feet, legs, buttocks, and genitalia.
  - Local tenderness and edema are common signs of envenomation.

- Edema and erythema should be measured repeatedly to assess progression.

Treatment for Common Sources of Envenomation

- General principles, regardless of etiology, are as follows:
  - Give supportive care and monitor for complications of shock and respiratory arrest.
  - Decontaminate the wound site, bandage it, and immobilize the area.
  - Assess the need for tetanus prophylaxis.
  - Evacuate patients with potentially severe bites and stings to definitive care.
  - Give antibiotics only for secondary infection.
- Bees and wasps
  - Bees, wasps, and other stinging insects account for roughly one-third of all envenomations. Stings may cause allergic symptoms and death from anaphylaxis.
  - Treatment
    - Remove stinger and decontaminate the area.
    - Most reactions are local and can be treated with acetaminophen and antihistamines.
    - Consider a steroid burst with antihistamine for large reactions.
    - Treat anaphylaxis with epinephrine.
      - Epinephrine 0.01 mg/kg of a 1:1000 solution, **OR**
      - A pediatric epinephrine autoinjector is available in a 0.15-mg dose, but a 0.3-mg dose should be given to children 30 kg and larger.
    - Steroids and antihistamines may prevent relapses.
- Snakes
  - Snakebite is an important medical emergency, although 25% to 49% of bites have no venom.
  - Bites are commonly on the extremities, usually from stepping on or handling a snake.
  - Signs and symptoms:
    - General signs include pain, edema, vomiting, headache, and shock.
    - Specific signs depend on the venom, the dose, and the site of injection.

        - Local effects include immediate pain, tender swelling spreading from the site of the bite, blisters, and necrosis.
        - Coagulation disturbances from hemotoxic venoms frequently present as bruising and bleeding from the gums or oozing from bite or venipuncture sites.
        - Neurotoxic effects include weakness, paralysis, and respiratory failure.
        - Rhabdomyolysis leading to renal failure can complicate bites.
    - Treatment
        - Immobilize the limb, remove jewelry, and evacuate the patient to a medical facility.
        - Do not use extraction, incisions, suction, tourniquets, or other unproven treatments.
        - Treat symptomatically and with supportive care.
        - Apparent hypovolemia is due to distributive shock. Treatment includes fluid boluses with isotonic fluid and may require vasopressors to restore perfusion.
        - Anticholinesterases can be considered as an adjunct treatment for neurotoxic envenomation. Administer neostigmine 0.01 to 0.04 mg/kg intramuscularly, intravenously (IV), or subcutaneously every 2 to 4 hours, depending on symptom severity and clinical progress (adult dosing 0.5–2.5 mg every 1–2 hours, up to 10 mg/24 hours).
        - For patients with an uncertain degree of neurotoxic envenomation, some experts advocate performing a "Tensilon test" first: administer atropine sulphate (50 μg/kg IV for children, up to 0.6 mg for adults) followed by IV edrophonium chloride (0.25 mg/kg for children, up to 10 mg for adults). Those with clear symptom improvement can be managed as above.
        - Antivenom (antivenin) should be used only for systemic or severe local envenoming. Dosage (number of vials) is based on the severity of symptoms and the patient's response to therapy. The patient may need repeated doses over time.

        - Antivenin is typically carried only at Role 3 facilities. Small units deploying without that level of support should identify referral sites through the combatant command (COCOM) or embassy prior to deployment.
        - Vipera berus (European viper), eastern coral snake, and Crotalidae (pit viper) antivenins are available through US military medical supply companies.
        - The World Health Organization maintains a worldwide venomous snake distribution and antivenom website with an image library (http://apps.who.int/bloodproducts/snakeantivenoms/database/).
        - Local Ministry of Health officials can help identify indigenous venomous snakes and potential sources of antivenom.
        - COCOMs have the authority to stock antivenom that has not been approved by the US Food and Drug Administration (FDA) at Role 3 facilities. A blanket investigational new drug application has been filed with the FDA for use of foreign antivenoms.
        - Use of antivenom must be reported through the COCOM to US Army Medical Research and Materiel Command to ensure regulatory compliance.
        - Epinephrine should be available to treat allergic reactions to antivenom.
- Scorpion
    - Scorpions are common around the world; most bites are only as dangerous and painful as a bee sting.
    - Most envenomations occur at night, mainly in bare-footed children or shepherds.
    - Signs and symptoms
        - "Tap test": tapping over the inoculation site will elicit significant pain.
        - The venom triggers an autonomic storm. Symptoms are more severe in young children and include neurotoxic symptoms, pulmonary edema, hyperthermia with rhabdomyolysis, and respiratory or heart failure.
    - Treatment
        - Symptomatic and wound care, including 1% lidocaine

injected into the wound for pain. For severe stings, provide sedation with short-acting benzodiazepines and opioid analgesia.
    - Treat serious respiratory or neuromuscular symptoms with supportive measures.
    - Antivenom is available in some countries. Centruroides antivenom was FDA-approved in the United States in 2011.
    - Consider prazosin (vasodilator therapy) for pulmonary edema.
- Black widow spider
  - Black widows have a characteristic red hourglass on their abdomen.
  - Death from a black widow bite is rare.
  - Black widows are commonly found outside in privies or in piles of wood or trash. Venom contains a neurotoxin.
  - Signs and symptoms of a black widow spider bite include pain at the site of the bite, muscle fasciculations, weakness, and ptosis.
  - Treatment
    - Provide supportive care (including pain relief) and monitor for severe symptoms.
    - Consider treatment adjuncts when indicated.
      - Calcium gluconate (50–100 mg/kg for fasciculations; maximum dose of 2 g).
      - Give muscle relaxants and benzodiazepines (diazepam) for severe muscle spasms.
      - Administer horse-serum-based antivenom for severe symptoms (available through US military medical supply).
      - Use of the antivenom is associated with a risk of anaphylaxis. Antivenom should be properly diluted per package insert instructions then infused over 30 minutes.
      - Prior the antivenom, pretreat the patient with IV diphenhydramine and an H2-blocker.
      - Epinephrine should be available to treat allergic reactions to antivenom.

- Brown recluse spider
  - Nicknamed "fiddle back" for its dark violin shape.
  - Generally found indoors, in dark areas like closets and basements.
  - Signs and symptoms
    - Classic lesion has an area of central necrosis within an erythematous ring ("blue-gray halo").
    - Hemolysis and renal injury can be seen.
  - Treatment
    - Supportive care.
    - Dapsone has been used in adults to reduce the extent of expanding necrotic lesions but may result in severe side effects (see Forks TP. Brown recluse spider bites. *Am Board Fam Pract*. 2000;13:415–23).
- Other
  - Tick bite paralysis is a rare life-threatening disorder caused by envenomation from ixodid tick bites primarily seen in Eastern Australia. Sporadic cases of tick paralysis have been seen in North America and Africa but are associated with other ticks.
    - Presents as a lower motor neuron paralysis progressing to respiratory failure similar to polio.
    - Removing the tick leads to rapid recovery.
    - Tick paralysis antivenom is available in Australia.
  - Caterpillars can have urticating hairs that cause dermatitis, and beetles can contain urticating substances that cause contact dermatitis (passive envenomation). Both exposures are treated symptomatically.

Chapter 40

Hypothermia, Cold, and Heat Injuries

Hypothermia

- Hypothermia occurs when core temperature drops to 35°C or below.
- Smaller children have larger surface-area-to-mass ratios and are more susceptible to hypothermia than adults.
- Hypothermia can occur rapidly in the setting of trauma regardless of ambient weather conditions.
- Heat is lost through four mechanisms:
  - radiation (roughly 60% of heat loss);
  - evaporation (another 20%–25% of heat loss, usually from sweating and respiration);
  - conduction, which is a concern with cold-water immersion or in the presence of wet clothing (clothes should be removed and the patient dried quickly); and
  - convection, which increases with exposure to wind chill (eg, in the desert at night).

Physiologic Effects

- Hematologic: in trauma patients, hypothermia exacerbates clotting dysfunction and is highly correlated with fatal outcomes.
- Cardiovascular: tachycardia is the initial heat-generating protective measure, but heart rate and mean arterial pressure decrease as core temperature decreases. Atrial, then ventricular, dysrhythmias occur as the temperature decreases below 32°C.
- Neurological: neuronal enzyme activity declines with hypothermia, but cerebral perfusion pressure is maintained until temperature reaches 25°C.

- Respiratory: initial tachypnea diminishes with a steady decline in minute ventilation and eventual cold bronchorrhea, which mimics pulmonary edema.
- Renal: as peripheral vasoconstriction creates total body fluid overload, there is rapid diuresis of dilute fluid; effects are enhanced by alcohol and cold-water immersion.
- Gastrointestinal: motility is decreased, leading to ileus.

Experience from Iraq and Afghanistan highlight the importance of preventing hypothermia during air evacuation. The Joint Theater Trauma System maintains a Clinical Practice Guideline on Hypothermia Prevention, Monitoring, and Management: available at http://www.usaisr.amedd.army.mil/clinical_practice_guidelines.html. See Chapter 11, Aeromedical Evacuation, for more details and equipment available to avoid hypothermia during patient transport.

Treatment

- Emergency treatment areas should be maintained at a temperature of 85°–90°F during casualty resuscitation.
- Check airway, breathing, and circulation; treat aggressively.
- Hypothermia associated with icy water immersion can lead to the diving reflex, with good neurological outcomes even after prolonged cardiopulmonary resuscitation and rewarming. This is not often the case with hypothermia occurring with complex polytrauma.
- The cold myocardium is resistant to defibrillation; continue cardiopulmonary resuscitation.
- Some patients convert spontaneously when their temperature reaches 32°C or above.
- Actively rewarm.
  - Remove all wet clothing, dry the patient, and wrap the patient with warm blankets. Use warming lights and/or a forced-air warming device on exposed skin.
  - Administer warmed intravenous fluids and consider warm nasogastric fluids and warm rectal lavage.

Cold Injuries

Frostbite

- Frostbite is cold damage to the skin that causes vasoconstriction and eventual tissue freezing.
  - Classify with a four-degree system, as for burns.
  - Treat by immersion in warm water (104.0°F–107.6°F) over 30 to 45 minutes. Rewarmed tissue is more susceptible to refreezing. If sustained thermal support is uncertain, consider delaying rewarming until the patient has reached definitive care.
  - Tetanus prophylaxis is indicated.
  - Pain is often severe and may require opioids.
  - Both ibuprofen and aspirin are recommended as adjunct therapies because of antiplatelet activity. Tissue plasminogen activator and prostacyclin have also shown efficacy in a limited number of small trials, but optimal medication management remains unclear.
  - Rewarmed tissue is vulnerable to reperfusion injury, manifested by large blisters that may be hemorrhagic.
    - These evolve into a hard eschar over 2 to 3 days and may appear similar to dry gangrene.
    - Surgical debridement and amputation should be delayed until a clear demarcation line develops, except when reperfusion injury leads to compartment syndrome, or when secondary infection is also present.

Chilblains

- Chilblains are localized erythematous or violaceous skin lesions that develop after sustained exposure to cold air and are often pruritic or painful.
- They can be precipitated by shorter periods of exposure in individuals with automimmune disorders.
- The process is self-limited, despite it having the same pathophysiologic cascade as frostbite.
- Manage by warming and preventing exposure.

Warm Weather Injuries

Although heat injuries are common in deployed soldiers, infants and young children are also predisposed to these injuries because of their high body-surface-area-to-mass ratio. There are three types of heat illness (same as in adults).

Heat Cramps

- Heat cramps are muscle cramps from dilutional hyponatremia.
- There are no central nervous system signs.
- Treat by repleting fluids and sodium.

Heat Exhaustion

- Heat exhaustion manifests with dizziness, nausea, vomiting, and weakness without significant change to mental status.
- Skin is moist from excessive sweating.
- Mild elevation of core temperature to 39°C–40°C.
- Treat by replacing fluids and sodium.

Heatstroke

- Heatstroke is a true medical emergency with a high rate of mortality; it needs to be recognized and treated promptly.
- It presents as a combination of altered mental status, dry skin, and hyperpyrexia.
- Monitor for complications, including rhabdomyolysis, acute kidney injury, encephalopathy, and hepatic failure with associated coagulopathy.
- Treat by immediate active cooling (eg, ice to the neck and groin, fanning the skin after spraying with water, etc), and administering intravenous fluids and diazepam to lessen shivering and cramping (which raise body heat) and to treat seizures.

Chapter 41

Casualties of Chemical, Biological, Radiological, Nuclear, and Explosive Weapons

Background

War respects no age limits and children are inevitably innocent casualties in every conflict. Children are likely to be among the victims of future terrorist attacks, including those potentially involving chemical, biological, radiological, nuclear, and explosive (CBRNE) agents. Children have also even been specifically targeted for attack. It is imperative that clinicians be familiar with the needs of children exposed to the effects of CBRNE agents.

Unique Considerations for Pediatric CBRNE Victims

Pediatric CBRNE victims differ from adults in myriad ways, which makes their care more problematic. Differences include:

- Anatomical and physiological differences.
  - Children have a higher surface-area-to-volume ratio, making them more susceptible to transdermal absorption of agents as well as to the effects of volume loss.
    - Children have a smaller relative blood volume than adults, which exacerbates the problem of fluid loss.
    - They have a less-well-keratinized epidermis, which enhances the problem of transdermal absorption.
  - Increased minute ventilation increases children's susceptibility to the effects of inhalational agents.
  - Children's less-mature blood–brain barrier permits greater penetration of certain toxins into the central nervous system.

- Differences in presentation.
  - Children may present with a different constellation of signs and symptoms or more intense disease than adults.
    - Venezuelan equine encephalitis, an incapacitant in adults, can be lethal in young children.
    - Melioidosis sometimes causes a parotitis in children but not in adults.
    - Few, if any, children are immunized against smallpox, while many adults may have some degree of residual immunity from long-distant vaccination.
    - Radiation injury disproportionately affects rapidly growing tissues, posing a special problem for young children.
- Treatment difficulties: Agents routinely used to treat adults may be contraindicated in young children (eg, fluoroquinolone and tetracycline antibiotics).
- Prophylactic difficulties.
  - Certain immunizations approved for adults are not licensed for use in children (eg, Anthrax Vaccine Adsorbed is only approved for those 18–65 years of age).
  - Some vaccines (eg, vaccinia and yellow fever) have a higher incidence of complications in children.
- Developmental considerations.
  - Children "live closer to the ground."
  - They are less able to flee, follow the instructions of public safety personnel, or distinguish reality from fantasy (eg, repeated media broadcasts of an event may be seen by young children as multiple events).
  - Children may be more prone to developing posttraumatic stress disorder than adults (see Gabbay, et al, in Further Reading).
  - Drugs and antidotes are often unavailable in pediatric (liquid) dosing forms.
  - Medical equipment is often unavailable in sizes suitable for children. In the domestic disaster response arena, National Disaster Medical System beds are often obtained through Department of Veterans Affairs hospitals, which have neither the facilities nor expertise to care for children.

Pediatric Chemical Casualties

The use of chemical weapons dates back to antiquity. There are hundreds of chemical agents that may be employed by terrorists. Below are common military-grade agents.

Nerve Agents

- Nerve agents are organophosphates that inhibit acetylcholinesterase; categorized as persistent nerve agents (eg, VX) and nonpersistent agents (eg, tabun, soman, and sarin).
- Signs and symptoms of exposure:
  - Cholinergic crisis caused by the accumulation of acetylcholine at the neuromuscular junction.
  - Use the **SLUDGE** mnemonic to evaluate a patient: **s**alivation, **l**acrimation, **u**rination, **d**efecation, **g**astrointestinal upset, and **e**mesis.
  - Central effects include ataxia, seizures, coma, and respiratory depression.
- No laboratory findings are available rapidly enough to be of use in the acute clinical setting; diagnosis must thus be suspected on the basis of clinical findings.
- Treatment: Administer atropine and 2-pralidoxime chloride (20–50 mg/kg intravenous [IV] with a maximum of 2 g over 30 minutes). There is no maximum dose for atropine, although experts recommend an initial dose of 0.05 mg/kg IV or intramuscular, titrating to effect (secretions are dry and the patient no longer shows signs of respiratory distress).
  - Experts feel that adult autoinjectors may be safely used even in young children.
  - Seizures should be treated with benzodiazepines (either diazepam [0.3 mg/kg] or lorazepam [0.1 mg/kg] initially, titrating to effect). The IV preparation of diazepam can be delivered rectally.

Blister Agents (Vesicants)

- Blister agents are cellular poisons that have been widely used. Mustard and lewisite are the most notable.

- Signs and symptoms of exposure to vesicants:
  - Blister agents burn the eyes, skin, and respiratory tract, with higher exposures leading to systemic effects and eventual bone marrow suppression.
  - Mustard gas has a delayed onset of symptoms, whereas the onset following lewisite exposure is more rapid.
- No laboratory findings are available rapidly enough to be of clinical use. (According to the US Centers for Disease Control and Prevention [CDC], only five or six laboratories in the country can confirm presence of the chemical. Also, leukopenia can indicate vesicant exposure [nonspecific], as it usually begins 3–5 days after exposure. With a white blood cell count less than 500, the prognosis is poor.)
- Treatment includes:
  - Rapid decontamination. Washing with soap and water is fine for most casualties. Dilute bleach from the standard military decontamination kit is equally effective.
    - The Reactive Skin Decontamination Lotion Kit (RSDL; Emergent BioSolutions Inc, Gaithersburg, MD) is available for use by the US military. It is intended to remove or neutralize vesicants, nerve agents, T-2 mycotoxin, and many pesticide-related chemicals from the skin.
    - This reaction starts immediately and neutralization is usually complete within minutes, then the chemical can be rinsed from the skin with water. The RSDL kit has not been approved for use on children by the US Food and Drug Administration.
  - Supportive care. Meticulous attention to fluid requirements is necessary. Blister agent burns require less fluid resuscitation than conventional burns; however, they are likely to be more serious in children than in adults.

Pulmonary Agents

- Chlorine and phosgene are the two primary examples of pulmonary agents; however, perfluoroisobutylene can be inadvertently released from burning military vehicles due to the chemicals in the paint used on these tactical vehicles.
- Signs and symptoms of exposure are as follows:

- Phosgene smells of newly mown hay.
- The chemicals generate hydrochloric acid in the exposed victim and lead to an oxygen free-radical cascade.
- The patient will first develop upper airway and conjunctival irritation, followed by wheezing and pulmonary edema.
- The more rapid the onset of symptoms, the more ominous the prognosis.

- No laboratory findings are specific, although monitoring of blood gases or transcutaneous oxygen saturation may help guide supportive therapy.
- Treatment is as follows:
  - Remove the victim from the area.
  - Provide supportive care.
    - Oxygen, albuterol, and ipratropium bromide are the mainstays of treatment. Children will often require higher doses of albuterol than adults and they are more tolerant of the associated tachycardia.
    - Enforced bed rest may ameliorate the pulmonary edema associated with exposure to phosgene. This edema usually occurs 4 to 6 hours after exposure, but may be delayed for up to 24 hours. Pulmonary agents are denser than air; therefore, child victims will have a proportionately higher exposure than adults (because they are lower to the ground).
    - Corticosteroid use is controversial and has not been shown to significantly improve outcomes from pulmonary edema. However, corticosteroids are known to diminish the inflammatory component of asthma, leading some experts to suggest their use (see Grainge C, and Rice P, in Further Reading).

Blood Agents

- Cyanide and the cyanogens are blood agents. Cyanide is a volatile chemical that disperses easily in air.
- Signs and symptoms of exposure are as follows:
  - Cyanide inhibits cytochrome a3 and halts normal oxidative metabolism, leading to cellular hypoxia and acidosis.
  - It strikes metabolically active tissues preferentially, specifically the heart and brain.

  - Cyanide's toxicity is dose dependent, with mild exposures causing tachypnea, tachycardia, and dizziness. More substantial exposures lead to seizures, coma, apnea, cardiac arrest, and eventual death.
- Laboratory findings: anion gap metabolic acidosis and elevated mixed venous oxygen saturation may be present, although treatment in an emergency situation must be based on clinical suspicion.
- Treatment includes movement to fresh air and administration of a cyanide antidote.
  - A traditional cyanide antidote kit consists of sodium or amyl nitrite followed by sodium thiosulfate.
  - Administer amyl nitrite via inhalation. Crush a 0.3 mL ampul of amyl nitrite and have the patient inhale for 15 to 30 seconds (may repeat in 3–5 minutes) until an IV sodium nitrite infusion is available.
  - Administer 3% sodium nitrite (0.33 mL/kg for patients with a normal hemoglobin of 12) to a maximum dose of 300 mg (10 mL of a 3% solution). Sodium nitrite should be infused slowly (over 5–10 minutes) to avoid hypotension. This causes the formation of methemoglobin, which in turn binds cyanide ion.
  - Follow with 25% sodium thiosulfate (1.65 mL/kg), to a maximum dose of 12.5 g (50 mL of a 25% solution). The liver uses the sodium thiosulfate to convert cyanide to thiocyanate, which is renally excreted.
  - Nitrite-induced hypotension as well as excessive methemoglobin formation can be hazardous to pediatric patients. Weight-based dosing of antidotes is especially important.
  - Hydroxocobalamin (vitamin B12a) is a newly approved and licensed single-agent antidote that can be used as an alternative to dual-agent antidote kits.
    - Recommended dose is 70 mg/kg (maximum 5 g) as a single infusion over 15 minutes. A second dose can be given in cases of severe intoxication.
    - It works by binding cyanide to create cyanocobalamin, a nontoxic form of vitamin B12 that is readily excreted in urine. This detoxification reaction does not result in

the generation of methemoglobin and does not interfere with the oxygen-carrying capacity of hemoglobin.

Riot Control Agents

- CS gas (military-grade tear gas), CN gas (mace), and capsaicin (pepper spray) are riot control agents designed to incapacitate their victims rather than permanently injure them.
- Signs and symptoms of exposure are as follows:
  - Mild exposure: ocular pain and lacrimation with eventual blepharospasm. Irritation of the nose, throat, and upper airway also occur.
  - High-dose exposure: the victim can have blistering of the skin, tracheobronchitis, and eventual pulmonary edema. Death, though rare, has been reported.
- Laboratory findings are nonspecific. Laboratory tests (other than arterial blood gasses) are neither helpful nor relevant.
- Treatment for riot control agents is supportive.
  - Remove the victim from the area and remove potentially saturated clothing.
  - For patients with pulmonary symptoms, provide supplemental oxygen, as needed.
  - For patients experiencing airway reactivity (wheezing), use albuterol, ipratropium bromide, and steroids as indicated.

Pediatric Biological Casualties

In 1999, the CDC developed a list of those agents that, if employed as weapons of terror, would pose the greatest threats to public health. "Category A" agents are deemed to present the greatest risk and routinely appear at the top of state-sponsored biological weapons threat lists.

Category A Agents

- Anthrax (etiologic agent *Bacillus anthracis*, a gram-positive spore-forming rod) is acquired via the inhalational route and typically has an incubation period of 1 to 6 days.
  - Signs and symptoms of exposure are as follows:
    - A flu-like illness ensues, characterized by fever, myalgia, headache, and cough.

        - A brief, intervening period of improvement sometimes follows 1 to 2 days of these symptoms.
        - Rapid deterioration then ensues; high fever, dyspnea, cyanosis, and shock mark this second phase. Hemorrhagic meningitis occurs in up to 50% of cases.
    - Laboratory findings: anthrax should be suspected with the finding of sporulating gram-positive bacilli in skin biopsy material (in the case of cutaneous disease) or in blood, sputum, and stool cultures.
        - Chest radiographs demonstrate a lung infiltrate with a widened mediastinum in the context of fever and constitutional signs, and in the absence of another obvious explanation (such as blunt trauma or postsurgical infection).
        - Confirmation is obtained by blood culture on standard media.
    - Treatment and prophylaxis: see Table 41-1.
    - Infection control: standard precautions. Anthrax is not contagious through the inhalational route.
- Plague (etiologic agent *Yersinia pestis*, a Gram-negative coccobacillary organism that demonstrates a "safety-pin" appearance with Gram or Wayson stain).
    - Signs and symptoms are as follows:
        - Symptoms of pneumonic plague include fever, chills, malaise, headache, and cough.
        - A classic clinical finding is blood-streaked sputum.
        - Chest radiographs may reveal a patchy consolidation.
        - Disseminated intravascular coagulation and overwhelming sepsis typically develop as the disease progresses, while meningitis occurs in 6% of cases. Without early therapy, plague can be rapidly fatal.
    - Untreated pneumonic plague has a fatality rate approaching 100%.
    - Laboratory findings: a diagnosis of plague can be suspected by the finding of bipolar, "safety-pin"-staining bacilli in Gram or Wayson stains of sputum or aspirated lymph node material.
        - Confirmation is obtained by culturing *Y pestis* from blood, sputum, or lymph-node aspirate.

Table 41-1. Pediatric Therapy of and Prophylaxis Against Diseases Caused by Category A Biothreat Agents

Condition	Appropriate Pediatric Regimens and Dosing*†
Anthrax (inhalational), therapy‡§	Ciprofloxacin 10–15 mg/kg IV q12h, **OR** Levofloxacin 8 mg/kg IV q12h, **OR** Doxycycline 2.2 mg/kg IV q12h, **AND** Clindamycin¥ 10–15 mg/kg IV q8h **AND** Penicillin G¶ 400–600k U/kg/d IV ÷ q4h **AND CONSIDER** Raxibacumab IV (> 50 kg: 40 mg/kg; 15–50 kg: 60 mg/kg; < 15 kg: 80 mg/kg)
Anthrax (inhalational), postexposure prophylaxis (60-day course§)	Ciprofloxacin 10–15 mg/kg PO q12h, **OR** Levofloxacin 8 mg/kg PO q12h, **OR** Doxycycline 2.2 mg/kg PO q12h
Anthrax (cutaneous, in setting of terrorism), therapy**	Ciprofloxacin 10–15 mg/kg PO q12h, **OR** Levofloxacin 8 mg/kg PO q12h, **OR** Doxycycline 2.2 mg/kg PO q12h
Plague, therapy‡	Gentamicin 2.5 mg/kg IV q8h, **OR** Doxycycline 2.2 mg/kg IV q12h, **OR** Ciprofloxacin 15 mg/kg IV q12h, **OR** Levofloxacin 8 mg/kg IV q12h
Plague, prophylaxis	Doxycycline 2.2 mg/kg PO q12h, **OR** Ciprofloxacin 20 mg/kg PO q12h, **OR** Levofloxacin 8 mg/kg PO q12h
Tularemia, therapy‡	Gentamicin 2.5 mg/kg IV q8h, **OR** Doxycycline 2.2 mg/kg IV q12h, **OR** Ciprofloxacin 15 mg/kg IV q12h
Tularemia, prophylaxis	Doxycycline 2.2 mg/kg PO q12h, **OR** Ciprofloxacin 20 mg/kg PO q12h
Smallpox, therapy	Supportive care

(**Table 41-1** *continues*)

Table 41-1 *continued*

Smallpox, prophylaxis	Vaccination may be effective if given within the first several days after exposure.
Botulism, therapy	Supportive care; antitoxin may halt the progression of symptoms but is unlikely to reverse them.
Viral hemorrhagic fevers, therapy	Supportive care; ribavirin may be beneficial in select cases.

*Do not exceed maximum recommended doses.
†Patients who are clinically stable after 14 days can be switched to a single oral agent (ciprofloxacin or doxycycline) to complete a 60-day course.
‡In a mass casualty setting, where resources are severely constrained, oral therapy may need to be substituted for the preferred parenteral option.
§Assuming the organism is sensitive, children may be switched to oral amoxicillin (80 mg/kg/d ÷ q8h) to complete a 60-day course. We recommend that the first 14 days of therapy or postexposure prophylaxis, however, include ciprofloxacin, levofloxacin, or doxycycline regardless of age. A three-dose series of Anthrax Vaccine Adsorbed may permit shortening of the antibiotic course to 30 days.
¥Rifampin or clarithromycin may be acceptable alternatives to clindamycin as drugs that target bacterial protein synthesis. If ciprofloxacin or another quinolone is employed, doxycycline may be used as a second agent, as it also targets protein synthesis.
¶Ampicillin, imipenem, meropenem, or chloramphenicol may be acceptable alternatives to penicillin as drugs with good central nervous system penetration.
**Ten days of therapy may be adequate for endemic cutaneous disease. A full 60-day course is recommended in the setting of terrorism, however, because of the possibility of a concomitant inhalational exposure.

    - *Y pestis* grows on standard blood or MacConkey's agar (often misidentified by automated systems).
  - Treatment and prophylaxis: see Table 41-1.
  - Infection control: droplet precautions.
- Tularemia (etiologic agent *Francisella tularensis*, a gram-negative coccobacillus)
  - Multiple clinical forms of endemic tularemia are known. Inhalational exposure in a terrorist attack would likely lead to pneumonia or to typhoidal tularemia, manifested as a variety of nonspecific symptoms, including fever, malaise, and abdominal pain.

- Laboratory findings: most findings (pneumonia, leukocytosis) are nonspecific. Confirmation can be obtained by the culture of *F tularensis* from blood using standard media.
- Treatment and prophylaxis: see Table 41-1.
- Infection control: standard precautions. Tularemia is not contagious.

- Botulism (etiologic agent can be any of seven toxins produced by *Clostridium botulinum*, a gram-positive anaerobic bacterium)
  - Signs and symptoms are as follows:
    - A latent period ranging from 24 hours to several days following exposure to botulism toxin is required before clinical manifestations develop. Although naturally occurring botulism typically involves ingestion of pre-formed toxins in improperly canned foods (and, occasionally from wounds contaminated with *C botulinum* spores), aerosol exposure to these toxins produces an identical clinical syndrome.
    - Initial symptoms involve cranial nerve dysfunction, manifested as bulbar palsies, ptosis, photophobia, and blurred vision owing to difficulty in accommodation.
    - Symptoms progress to include dysarthria, dysphonia, and dysphagia.
    - Finally, a descending symmetric paralysis develops and death may result from respiratory muscle failure.
  - There are no specific laboratory findings. Antibody assays are not helpful.
  - Treatment and prophylaxis: see Table 41-1.
  - Infection control: standard precautions. Botulism is not contagious.
- Smallpox (etiologic agent Variola virus, a member of the *Orthopoxvirus* genus of large double-stranded deoxyribonucleic acid viruses)
  - Signs and symptoms
    - During the 7- to 17-day incubation period, the virus replicates in the upper respiratory tract, ultimately giving rise to a primary viremia.
    - Amplification of the virus occurs following seeding of the liver and spleen, and a secondary viremia then develops.

        - Clinical illness begins abruptly and is characterized by fever, rigors, vomiting, headache, backache, and extreme malaise.
        - The classical exanthem begins 2 to 4 days later.
            - Macules are initially seen on the face and extremities; these macules progress in synchronous fashion to papules, then to pustules, and finally to scabs.
            - As the scabs separate, survivors can be left with disfiguring, de-pigmented scars.
            - The synchronous nature of the rash and its centrifugal distribution distinguish smallpox from chickenpox, which has a centripetal distribution.
            - Death occurs in 30% of Variola major patients.
    - Laboratory findings: the classic appearance of an *Orthopoxvirus* can be seen on electron microscopic examination of material obtained from lesions.
    - Treatment and prophylaxis: see Table 41-1.
    - Infection control: strict airborne and contact precautions.
- Viral hemorrhagic fevers (etiologic agents include a number of ribonucleic acid viruses belonging to one of four taxonomic families: the *Arenaviridae, Filoviridae, Flaviviridae*, and *Bunyaviridae*).
    - Signs and symptoms: although the diseases produced by these agents differ considerably in their clinical manifestations, severity, and modes of transmission, they share a propensity to cause a bleeding diathesis.
    - Although no laboratory finding is specific, many patients with viral hemorrhagic fever show evidence of disseminated intravascular coagulation.
    - Treatment and prophylaxis: see Table 41-1.
    - Infection control: contact precautions. Although viral hemorrhagic fever viruses are transmitted principally via blood and body fluids (thus necessitating contact precautions), the recent Ebola virus outbreak in West Africa has demonstrated the ease with which these body fluids (blood, diarrheal stool, vomitus) can be aerosolized and the uncompromising nature of small breaks in protective technique. The CDC thus recommends meticulous attention to the donning and doffing of personal protective equipment

and the institution of a combination of airborne, droplet, and contact precautions when dealing with suspected Ebola patients.

Pediatric Nuclear and Radiological Casualties

Nuclear casualties result from the immediate effects of a nuclear detonation, which includes blast and thermal components. Radiological casualties result from exposure to ionizing radiation and contamination with radioactive material. Fallout containing these fission products is highly radioactive and exposure to it will result in severe irradiation injury. The majority of nuclear detonation fission products decay extremely rapidly. By 48 hours after detonation, the overall dose rate is less than 1% of the initial fallout output, although specific "hot spots" with higher dose rates will occur. A "dirty bomb" scatters a radioactive source across an area in a manner similar to local fallout. Radiation output decays at the steady half-life rate associated with the specific isotope.

Children's body habitus and shorter distance from trunk to ground means they receive a radiation dose several times higher than adults from "ground shine." This risk is compounded by the greater inhalation and ingestion hazards associated with the same anatomical (as well as developmental) differences (eg, the preponderance of pediatric thyroid injuries following the Chernobyl incident). Ionizing radiation exposure is responsible for total body injury and may be more hazardous to children due to their overall rapid cell turnover rate. Children are also at higher risk from exposure than adults because of their increased metabolism, higher caloric requirements, higher baseline respiratory rates, thinner skin, larger surface-to-mass ratio, increased fluid losses secondary to burns, and greater sensitivity to the volume and electrolyte deficits induced by diarrhea, nausea, and vomiting. Their small physical mass makes them less tolerant of radiation total-body injury.

Basic clinical management of children exposed to radiation does not differ from adults. Treatment should include symptomatic relief of nausea and vomiting, pain management, and infection control.

Medical Effects of a Nuclear Detonation

- Blast
  - Overpressure results in pulmonary, solid organ, and ear damage, as the instantaneous pressure change does not allow for internal stabilization. Consequently, pressure gradients that would ordinarily cause no damage result in structural injury. For instance,
    - A pressure wave of 5 psi is sufficient to rupture eardrums.
    - 15 psi can cause alveolar hemorrhage.
  - The physical effects of the blast include debris entrapment, crush injuries, translocation injury, and missile wounds caused by blast winds (eg, flying glass shards).
  - Nuclear detonation results in sudden hurricane-force winds sufficient to pick up a child and throw him or her into a solid structure.
  - Collapse of buildings, walls, and other structures will cause entrapment.
  - Disorientation due to sudden destruction of the normal environment, loss of family members, and trauma will diminish normal survival instincts.
  - Children will be particularly prone to an inability to distinguish potential escape routes.
  - Hiding in close quarters may offer immediate comfort, but may result in fatal entrapment.
- Thermal
  - Partial and full-thickness burns will occur both from secondary fires and from the direct thermal pulse.
  - In the detonation of a weapon of 10 kilotons or less, most casualties who receive direct infrared burns due to the thermal pulse will also receive lethal-dose irradiation.
  - The infrared burns will "mature" similar to sunburn and may not be immediately evident.
  - Fires caused by the blast will ignite rubble and cause traditional thermal injuries. These burns must be treated aggressively, as any concomitant irradiation injury will worsen the total prognosis for a given "combined injury" patient.

- Retinal burns will occur if a child looks directly at the detonation.
  - These burns result from the lens focusing the infrared pulse on the retina.
  - Total foveal destruction may occur, resulting in permanent loss of central vision.
  - Flash blindness is a temporary condition lasting several minutes and is due to massive overstimulation of the retinal cells. The brilliance of the detonation is reflected in the atmosphere and off of structures and can cause temporary "flash-bulb" effects at a distance of tens of miles at night. During daylight, the effect still occurs but with a lesser range.
- Children may be subject to additional injury due to a parent's loss of control of motor vehicles in the immediate aftermath of a nuclear detonation.

- Ionizing radiation exposure
  - Effects are directly dose-related; the sooner physical effects are expressed, the more severe the damage.
  - Early nausea and vomiting within 4 to 12 hours indicates that immune system failure may occur at 5 to 10 weeks postexposure.
  - Acute local skin erythema in the first hours secondary to the infrared pulse indicates a high probability of lethal injury.
  - Radiation dermatitis is related to effective dose.
    - Erythema occurs at 6 to 20 Sv (600–2,000 rem).
    - After 20 to 40 Sv, the skin will ulcerate in approximately 14 days, beginning in the highest-dose region and progressing to lower dose areas.
    - Above 3,000 Sv, the skin will blister immediately. This local dose will probably be associated with a concomitant gamma total-body injury.
    - Survival following exposure to doses above 10 Sv (1,000 rem) is generally only possible when exposure is localized (as opposed to whole-body exposure).
  - Laboratory findings: leucopenia may be seen within 2 to 4 days of a radiation exposure; anemia and thrombocytopenia are later findings.

- Treatment: the need for acute management is generally limited to patients experiencing dose rates greater than 1 cGy per hour.
- Treatment and prevention of neutropenia with colony stimulating factors (CSFs) may prevent death from sepsis and lessen the duration of the need for prophylactic antibiotics.
  - CSF administration may need to be initiated at a lower estimated radiation dose (eg, 2 Gy) than has been recommended for adults.
  - Bone marrow stimulation with enhancement of neutrophil recovery is based on cancer chemotherapy clinical experience with CSFs, as well as limited case histories of accidental irradiation.
  - Both filgrastim (5 μg/kg/day subcutaneous) and sargramostim (250 mg/m^2/d subcutaneous) have been used in radiation accident victims; neutrophil recovery appeared to be hastened, but no definitive conclusions regarding the effectiveness can be made (see *NATO Handbook on the Medical Aspects of Defensive Operations [Nuclear]*, in Further Reading).
  - Use of fluoroquinolone antibiotics is appropriate during the period of absolute neutropenia; these agents are currently available in the Strategic National Stockpile.
- Specific infections should be treated in accordance with standard practice.

Radiological Contamination

Contamination evaluation and therapy must never take precedence over the treatment of acute injury. Unlike with exposure to persistent chemical agents, caregivers are not at risk of irradiation from contamination on a patient. Normal clothing serves as a barrier and significantly limits cross-contamination. Life- and limb-saving interventions should thus be initiated prior to decontamination.

- External contamination
  - External contamination is usually in the form of dust and can be washed off the skin using the local institution's

standard gentle cleansing protocols or soap and water. A human body cannot be so contaminated as to preclude simply washing the radiological contaminants down the drain, although the local sewage treatment system provider should be notified when time permits. Specimens of effluent and large particulates can be saved in a segregated location for later forensic analysis.

- Contaminated clothing should be removed, individually bagged, and transported to a location away from patients and responders.
- Signs and symptoms of external contamination
  - When beta particles are emitted on or close to the skin, they cause direct cell damage. The skin damage becomes evident as the cells migrate to the surface via normal desquamation ("beta burns").
  - The stratum corneum consists of dead tissue, so there is normally no initial visible effect.
- Laboratory findings: standard radiac instruments (such as a Geiger counter) detect and measure gamma radiation; many also detect and measure alpha and beta activity.
- Treatment and prophylaxis: thorough decontamination will prevent further injury and should be undertaken as soon as is practical. Decontamination should not be so intense as to cause skin irritation.

- Internal contamination
  - Internal contamination will occur when children ingest, inhale, or are wounded by radioactive material.
  - Signs and symptoms of internal contamination
    - Normal metabolism of the nonradioactive isotope of the same element determines the metabolic pathway of a radionuclide.
    - Once a radionuclide is absorbed, it crosses capillary membranes through passive and active diffusion mechanisms and then is distributed throughout the body. The rate of distribution to each organ is related to organ metabolism, the ease of chemical transport, and the affinity of the radionuclide for chemicals within the organ.

- The liver, kidney, adipose tissue, and bone have higher capacities for binding radionuclides due to their high protein and lipid makeup.
- Nursing mothers should discontinue breast-feeding when maternal internal contamination is suspected, as radionuclides are concentrated and excreted in breast milk.
- Inhaled particles less than 5 μm in diameter may be deposited in the alveoli and microbronchioles.
- Larger particles will be cleared to the oropharynx by the mucociliary apparatus, where they will be swallowed and processed through the digestive tract.
- Soluble particles will either be absorbed into the bloodstream directly or pass through the lymphatic system.
- Most radioisotopes in nuclear weapons, such as plutonium, uranium, radium, and strontium, are insoluble and, when ingested, pass through the gastrointestinal tract unabsorbed. They will continue to irradiate surrounding tissue (eg, alpha- and beta-emitting isotopes are the most damaging to the alveoli) until they are cleared. Fibrosis and scarring are more likely to occur due to resultant localized inflammatory response.

- Swallowed radioactive materials are handled like any other elements in the digestive tract, although they do provide a source of continuing radiation exposure while in transit though the intestine. Absorption depends on the chemical makeup of the contaminant and its solubility.
  - Certain radioactive elements, such as cesium (a potassium analogue) and iodine, are readily absorbed.
  - Avoiding contaminated food and eating only packaged foodstuffs significantly decreases internal contamination by this route.
  - Infants, with their predilection for placing items in their mouths, must be kept away from contaminated surfaces.

- The skin is impermeable to most radionuclides, but any element that is in a water-soluble form may pass through.
  - Skin is particularly vulnerable to water containing tritium as the hydrogen moiety.
  - Open wounds and burns provide a direct route for absorption, allowing particulate contamination to bypass the epithelial barrier. Thorough irrigation and cleansing is mandatory to diminish uptake by this route; wounds must be meticulously cleaned and debrided when they occur in a radiological environment. After the surrounding skin is clean, wounds should be carefully examined with an appropriate radiation detector (note that any fluid in the wound may hide weak beta and alpha emissions from detectors).

- Laboratory findings: standard radiac instruments (such as Geiger counters) detect and measure gamma radiation; many also detect and measure alpha and beta activity.
- Treatment and prophylaxis
  - Mobilizing or chelating agents should be initiated as soon as practical when the probable exposure is judged to be significant, since they are more effective the sooner they are given. Unfortunately very few clinicians have any experience in the use of many of these drugs. Clinicians should carefully review the label guidance, and consultation with radiation countermeasure experts should be sought, if possible. Assistance can be obtained from the Armed Forces Radiobiology Research Institute (Uniformed Services University) in Bethesda, MD (http://www.usuhs.edu/afrri/), and from the Radiation Emergency Assistance Center/Training Site (Oak Ridge Associated Universities, PO Box 117, MS-39, Oak Ridge, TN 37831; www.orise.orau.gov/reacts).
    - Propylthiouracil or methimazole may reduce the thyroid's retention of radioiodine.
    - Chelating agents may be used to remove many metals from the body.
  - Gastric lavage and emetics can be used to empty the stomach promptly and completely after the ingestion of poisonous materials.

- Purgatives, laxatives, and enemas can reduce the residence time of radioactive materials in the colon.
- Ion exchange resins limit gastrointestinal uptake of ingested or inhaled radionuclides.
- Ferric ferrocyanide (Prussian blue) and alginates have been used in humans to accelerate fecal excretion of cesium-137.
- Blocking agents, such as stable iodide compounds, must be given as soon as possible after exposure to radioiodine. Potassium iodide blocks radioiodine incorporation by the thyroid gland, but does not afford protection against acute irradiation injury.
- Calcium ethylenediaminetetraacetic acid (EDTA) is used primarily to treat lead poisoning and must be used with extreme caution in patients with preexisting renal disease.
- Diethylenetriaminepentaacetic acid (DTPA) is more effective in removing many of the heavy metal multivalent radionuclides.
  - Chelates are water soluble and are excreted in urine.
  - DTPA metal complexes are more stable than those of EDTA and are less likely to release the radionuclide before excretion.
  - Repeated use of calcium salt can deplete zinc and cause trace metal deficiencies.
  - Ca-DTPA should be used carefully in infants and children and only as an initial dose.
  - Dimercaprol (British anti-Lewisite) forms stable chelates with mercury, lead, arsenic, gold, bismuth, chromium, and nickel, and therefore may be considered for treating internal contamination with the radioisotopes of these elements.
  - Penicillamine chelates copper, iron, mercury, lead, and gold.

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Chapter 42

Children in Disasters

Background

- An estimated 350 million people are affected by natural disasters annually, of which 50% to 60% are children.
- Children have unique physiological, anatomical, and psychosocial vulnerabilities, responses, and needs in a disaster, particularly in a chemical, biological, radiological, nuclear, or explosive situation (see Chapter 41, Casualties of Chemical, Biological, Radiological, Nuclear, and Explosive Weapons, for further details), including:
  - shorter height/larger head (trauma risk),
  - higher minute ventilation (inhalation risk),
  - larger body-surface-area-to-mass ratio (exposure and hypothermia risks),
  - lower developmental stage (inability to escape), and
  - more immature psychological stage (separation anxiety).
- In the acute phase, mortality from a disaster reflects the age distribution of the population.
- Subsequently, mortality increases in the most vulnerable populations, including children, women, and the elderly, particularly for children under 5 years of age.
- Leading causes of death in a disaster include trauma, diarrhea and dehydration, communicable diseases (measles, malaria, acute respiratory infections), and malnutrition.
- As a result of weak infrastructure, poor early warning systems, and inadequate risk-reduction strategies, developing nations are disproportionately affected by disasters.

Definitions

- A disaster is defined as a sudden phenomenon or hazard that impacts a population, leading to increased morbidity, mortality, and loss of livelihood.

- A disaster exceeds the internal capacity of a population to respond without additional external aid or resources.
- Disasters may be natural or human-provoked in etiology.
  - Natural disasters: cyclones, earthquakes, floods, tornados, tsunamis, volcanoes, and wildfires.
  - Human-provoked disasters: industrial or technological events, terrorism, violence, complex emergencies (conflict, genocide, famine), pandemics, and epidemics.
- The impact of a disaster is proportional to the severity, duration, and vulnerability of the effected population.
  - Impact = Vulnerability × Phenomenon.
  - Vulnerability factors can be human, ecological, economical, social, legal, or political.
  - Characteristics of phenomena include timing (rapid versus slow onset), natural disasters, and human-provoked events.
- The disaster cycle is a predictable continuum useful for characterizing the phase of a disaster as well as for organizing planning, preparation, and response (Figure 42-1).
- Challenges that are unique to disaster response include:
  - warning and evacuation;
  - urban search, rescue, and recovery;
  - triage and casualty distribution;
  - large-scale victim and responder mental health issues; and
  - communication and coordination.

Military Disaster Response

- The US government responds to 70 to 80 disasters per year.
- Of these, the Department of Defense (DoD) provides some form of assistance—ranging from a single aircraft to larger task forces—to only 10% to 15%.
- DoD acts in support of the Department of State. The United States Agency for International Development (USAID) Office of Foreign Disaster Assistance (OFDA) leads the response.
- DoD is generally not a first responder in foreign disaster response (FDR). DoD is involved when:
  - host-nation capacity is overwhelmed;
  - a unique, clearly defined service can be provided; and
  - civilian authorities request assistance.

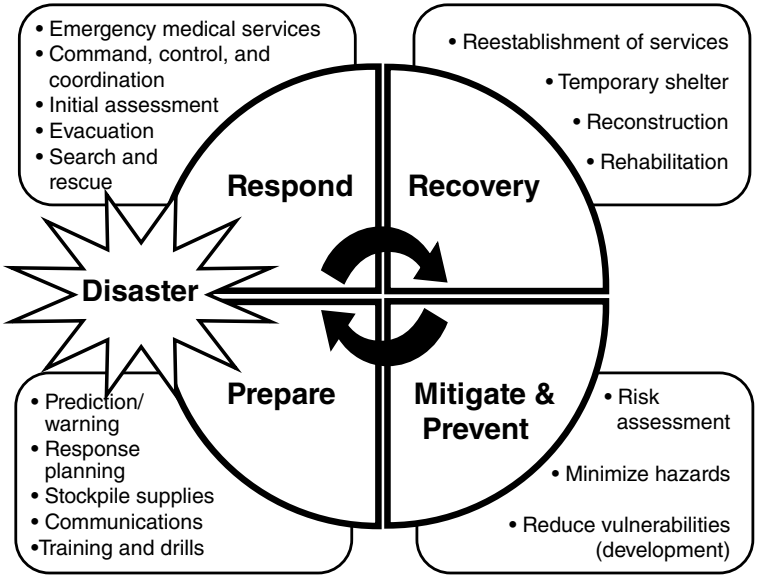


Figure 42-1. The disaster cycle is a predictable continuum useful for characterizing the phase of a disaster as well as for organizing planning, preparation, and response.

- DoD's mission is short and limited in focus such that it can be handed over to the host nation or US civilian agencies as soon as the situation is stabilized to avoid "mission creep."
- For further details of DoD concept of operations and tactics, techniques, and procedures for FDR, see *Department of Defense Support to Foreign Disaster Relief* (US Department of Defense. *Department of Defense Support to Foreign Disaster Relief*. Washington, DC: DoD; July 13, 2011. http://fas.org/irp/doddir/dod/disaster.pdf).

Planning

- Beyond standard force health protection plans, FDR planning is a complex process with many critical steps requiring coordination with USAID/OFDA and the joint task force (Exhibit 42-1).

Exhibit 42-1. Pre-Deployment Medical Officer Disaster Planning

- Conduct medical intelligence preparation of the operational environment (MIPOE).
- Obtain and interpret pertinent information on host nation and nongovernmental organization medical infrastructure, capabilities, and needs.
- Assess for and mitigate operational health threats.
- Establish a mass casualty plan.
- Develop a patient-tracking system.
- Establish an evacuation policy for patient movement.
- Estimate medical supply needs and preplan initial resupply.
- Ensure medical staff health and cultural education.
- Conduct medical staff training and drills.

Adapted from: Department of Defense. *Department of Defense Support to Foreign Disaster Relief*. Washington, DC: DoD; July 13, 2011. https://www.jllis.mil/JSCC/index.cfm.

- Pediatric triage, emergency care, hospital planning, and supplies need to be addressed as part of all command disaster response plans.
- Unique challenges to a planning a response may include:
  - adequate variety and number of pediatric supplies,
  - pediatric decontamination equipment and protocols,
  - pediatric assessment training,
  - availability of pediatric specialists,
  - medications specific to children, and
  - limited operating room, intensive care unit, postanesthesia care unit, and inpatient beds.
- Disaster response training should include an "all-hazards" approach that is standardized and consistent.

Pediatric Triage

- Pediatric triage is a critical element of systematically responding to a mass casualty incident (MCI) and surge.
- The goal of triage is the same for children as for adults: to prioritize patients for treatment and transport and save as many patients as possible with the resources available.

- The most basic triage algorithm is the pediatric assessment triangle used to rapidly classify a patient based on appearance, color, and breathing (see Chapter 1, Basic Approach to Pediatric Trauma).
- MCI triage algorithms sort patients into color-identified care categories, including minor (green), immediate (red), delayed (yellow), and dead (black).
- Triage is readily tracked with color-coded tags that record identification, vitals, assessment, categorization, and interventions.
- If triage tags are unavailable, medical report can be directly marked on a patient or wound dressing, though not on bed sheets because loss of data in transfer.
- The SALT (sort, assess, life-saving interventions, treatment and/or transport) triage, supported by the Centers for Disease Control and Prevention (Figure 42-2), is the nationally accepted, all-hazards, mass casualty triage for all populations (adult and pediatric).
- For pediatric patients, the combined START/JumpSTART algorithm (Figure 42-3) is preferred, as it provides a decision-making process that explicitly accounts for pediatric physiology and normative values.
- Retriage should be performed at each new level of care. Additionally, triage is a bidirectional process and should allow for the recategorization of a patient at any point in the process as either higher or lower priority.

Hospital Planning and Surge Capacity

- In a disaster or pediatric MCI, there may be the unexpected need to rapidly surge inpatient capacity, particularly critical care, beyond normal operations. Additional disaster response and mass critical care supplies and equipment needs for children must be considered (see the Comprehensive Pediatric Equipment Sizing table in Appendix C; Exhibit 42-2).
- Contents of service-specific supply augmentation kits (eg, Pediatric Augmentation Set [625A]; see Resources for Deployed Physicians in Appendix A of this book) should be compared to the Comprehensive Pediatric Equipment Sizing table in Appendix C and to Exhibit 42-2 to identify additional supplies, equipment needs, and gaps.

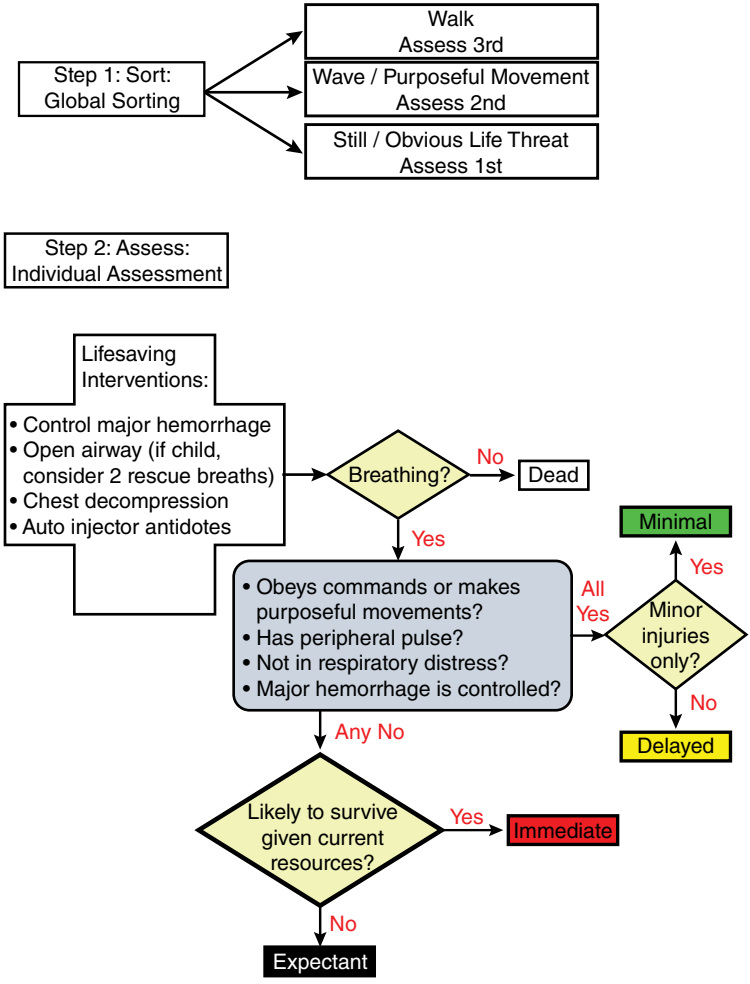


Figure 42-2. The SALT (sort, assess, life-saving interventions, treatment and/or transport) triage, supported by the Centers for Disease Control and Prevention, is the nationally accepted, all-hazards, mass casualty triage for all populations (adult and pediatric).
Reproduced with permission from: US Department of Health and Human Services, National Institutes of Health, US National Library of Medicine. Chemical Hazards Emergency Medical Management website. *SALT Mass Casualty Triage Algorithm*. http://chemm.nlm.nih.gov/salttriage.htm. Accessed April 9, 2015.

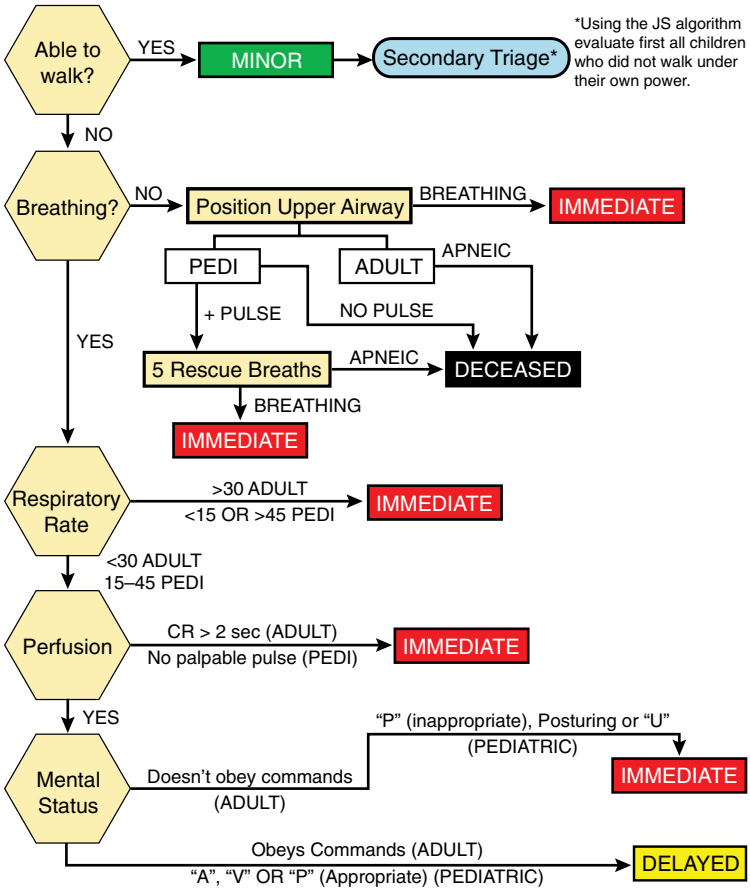


Figure 42-3. The combined START/JumpSTART algorithm is preferred for pediatric patients.
Reproduced with permission from: Lou Romig MD, FAAP, FACEP.
A: alert
CR: capillary refill
JS: JumpSTART
P: responds to painful stimuli
PEDI: pediatric
U: unresponsive to noxious stimuli
V: responds to verbal stimuli

Exhibit 42-2. Additional Disaster and Critical Care Supplies

Airway Management
- Nasal cannulas and simple face masks
- Oxygen source with flow meter
- Self-inflating bags, child and adult sizes
- Laryngoscope handles with batteries
- Ventilators with humidifiers and pediatric circuits (inspiratory flow/pressure sensor sensitive enough to ventilate infants)

Intravascular Access and Fluid Management
- Boards, adhesive tape, tourniquets
- Buretrol chambers and IV tubing, pediatric sizes
- Butterfly needles (21 and 23 gauge)
- Fluids: D_5NS, D_5 ½NS, NS, and lactated Ringer's
- Intraosseous needles (15 and 18 gauge)
- Vasoactive drugs (dopamine, epinephrine)

Miscellaneous
- Broselow Pediatric Emergency tapes
- Chest drains
- Geiger counter (if there is suspected radioactive contamination)
- Personnel protective equipment (gloves, masks, gowns)
- Splints and gauze padding
- Supply carts, portable
- Thermal control (blankets, radiant warmer/cradle, lamp)
- Warm water source, with showers for decontamination

Monitoring Equipment
- Electrocardiogram electrodes, pediatric sized
- End-tidal CO_2 monitor
- Portable monitor/defibrillator with pediatric paddles
- Pulse oximeter with reusable and nonreusable sensors
- Pediatric sphygmomanometer
- Testing: blood gas, glucose, and urinalysis
- Thermometers

Sedation, Analgesics, Antimicrobials, and Nutrition
- Narcotics, ketamine, benzodiazepines
- Antibiotics, antifungals, antitoxins
- Age-appropriate enteral feeding formulas

CO_2: carbon dioxide
IV: intravenous
NS: normal saline

- In extenuating circumstances, consideration should be given to the reuse of some consumable goods following sterilization, particularly during a pandemic outbreak.
- Altered standards of care may be required. An altered standards-of-care policy is best determined prior to an MCI and should allow for in-hospital triage to lower levels of care, early transfer to lower levels of care, and early discharge.
- "Reverse triage" risk-stratifies patients according to readiness to discharge and seeks to discharge minimal- and moderate-risk patients to expand inpatient capacities.

Assessment

- Following a disaster, the initial assessment is one of the most important functions of the disaster response team.
- The initial assessment focuses on the situation or needs, establishing:
  - extent and scope of the disaster,
  - vulnerable populations,
  - food and nonfood needs,
  - host-nation internal response capacities, and
  - extent of other nations' and agencies' responses, as well as
  - identifies priorities for intervention.
- Monitoring the crude mortality rate (CMR) in a disaster is a key indicator of disaster acuity, phase, and response efficacy.
- CMR is measured in deaths per 10,000 inhabitants per day.
- The emergency threshold is an increase of more than double the baseline CMR, generally greater than 1 death/10,000/day or an under-five mortality rate of 2 deaths/10,000/day.
- Refer to the USAID OFDA *Field Operations Guide for Disaster Assessment and Response* (https://scms.usaid.gov/sites/default/files/documents/1866/fog_v4.pdf) for greater detail on how to conduct a disaster assessment, and Chapter 43, Humanitarian Operations, for additional information on postdisaster disease assessment, surveillance, and prevention.

Emergency Relief and Vulnerability Reduction

- Essential emergency relief measures should include the elements identified by the World Health Organization (Exhibit 42-3).

Exhibit 42-3. Essential Emergency Relief Measures

- Perform a rapid assessment
- Provide adequate shelter and clothing
- Provide adequate nutrition
- Provide elementary sanitation and clean water
- Institute a diarrheal disease control program
- Immunize against measles
- Provide vitamin A supplementation
- Reestablish and improve primary medical care
- Organize human resources and coordinate activities

Adapted from: Berman S. *Pediatric Education in Disasters Manual*. Buenos Aires, Argentina: AAP/ACINDES; 2009. http://www.aap.org/disasters/index.cfm. Accessed February 2, 2015.

- Measures to reduce pediatric vulnerability are reviewed in Exhibit 42-4.

Exhibit 42-4. Measures to Reduce Pediatric Vulnerability

- List all vulnerable populations
- Provide identification tags for all children
- Identify local community leaders, especially females, who can care for vulnerable populations
- Place families and groups of neighbors together
- Guarantee care and safety
- Include considerations for vulnerable populations in distribution systems
- Prioritize searches for parents and family of vulnerable children

Adapted from: Berman S. *Pediatric Education in Disasters Manual*. Buenos Aires, Argentina: AAP/ACINDES; 2009. http://www.aap.org/disasters/index.cfm. Accessed February 2, 2015.

Patient Evacuation

- The following should be considered as part of determining need to evacuate a patient:
  - eligibility criteria and sponsorship guidelines,
  - available evacuation resources and routes,
  - ability to ensure accompanying guardian,
  - pediatric capabilities of medical treatment facilities within (and adjoining) the operational area, and
  - capacities of host nation/nongovernmental organization facilities that will assume care at transfer/discharge.

Psychological Impact

- Disasters have a profound psychological impact on children due to direct impact or injury, perceived threat, caregiver separation, witness to injury or death, and other factors.
- In addition to normal reactions, children may experience both acute and chronic sequelae, such as stress, anxiety, depression, and posttraumatic stress disorder, among others.
- Refer to Chapter 37, Behavioral Healthcare of Children in Austere Environments, for further information and interventions.

Further Reading

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Chapter 43

Humanitarian Operations and Medical Civil-Military Activities

There are several situations in which militaries may be tasked with providing humanitarian assistance to foreign civilians. Military physicians may provide direct patient care, be involved with public health projects, or serve as field surgeons who guide commanders in planning and executing humanitarian activities.

US military personnel may be authorized or ordered to treat nonmilitary patients and address the health needs of foreign civilian populations in the following situations:

- incidental activities during combat operations,
- support for counterinsurgency and stability operations,
- disaster response (see Chapter 42, Children in Disasters),
- mass migration events, and
- training activities.

General Principles of US Military Medical Humanitarian Activities

Command-directed medical rules of engagement (MEDROEs) and funding authorities regulate US military medical humanitarian activities. Activities are determined at echelons above the local tactical command. They are typically published in plans and orders for operations. Questions should be directed to the unit medical planner or the medical plans and operations cell at the next higher headquarters. Objectives may include relieving suffering, promoting health, improving security, providing readiness training, or a combination of these purposes. Medical activities are sometimes viewed as another tool in a commander's "tool box" and may be used to support a larger mission. Keys to success include:

- **Clarity of goals and objectives** of the activity, including any non-health–related objectives, such as improved security, "winning hearts and minds," and training US medical forces.
  - This may require an honest conversation between the commander and his or her senior medical advisor regarding the appropriateness of medical activities to achieve the commander's desired effects.
  - Medical activities may not be the best "tool" to achieve the desired effect and can have undesired or unanticipated second- and third-order effects.
- **Adequate coordination** with host-nation medical personnel and, where appropriate, nongovernmental organizations (NGOs) working in the area.
- **Using medical intelligence** to understand the local population's disease and injury. Sources of medical intelligence include:
  - World Health Organization (WHO) and its regional suborganizations.
  - Host-nation ministry of health (MoH) at national, regional, and local levels.
  - National Center for Medical Intelligence.
- **Understanding the host-nation health system** and key leader health priorities.
- **Awareness of important cultural patterns** that affect health, including:
  - cultural beliefs about causes of disease, and
  - cultural "hot buttons" (eg, treatment of women and children, gender roles in health care).
- **Avoiding a US medical-centric viewpoint**; understanding global health initiatives from organizations such as the WHO or host-nation MoH.
- **Planning at strategic, operational, and tactical levels**. Answering the following questions will help achieve this:
  - Does the particular activity support larger host-nation health campaigns?
  - Does the activity build upon a series of events designed to create larger or more sustained effects? Is it appropriately synchronized to maximize benefit?

- Is the activity vetted by the host-nation health authorities at national, regional, and local levels?
- Does the activity use health strategies that are similar to those used by the host nation?
- Will the activity complement the host-nation health system and contribute to improved relations between the host-nation government and health system and the local population?
- Does the team/unit have all the required skills to achieve the desired effects (including both medical and nonmedical skills, such as adequate linguists, logistics, transportation, communication, and security expertise)?
- Are medications and equipment appropriate for the anticipated operating environment (eg, is refrigeration available if required)?
- Have referral and transfer networks been established?
- Are there established mechanisms for follow-on patient care?

- **Upholding ethical standards**, regardless of the objectives; all medical activities must be in accordance with the highest ethical standards.
  - First, do no harm. Be aware of unintended consequences of interventions, such as danger to patients at treatment areas and after they leave the secured area.
  - If providing direct care, each individual patient must be provided the best possible care under the specific conditions.
  - Aim for a standard of care that is aligned with that of the local system and, to the extent possible, sustainable with local resources. Trying to practice US-style, high-tech medicine may not be appropriate.
  - Practice educated empiricism. Practicing medicine using observations and clinical skills informed by knowledge of local health conditions without laboratory and radiological confirmation is frequently the norm.
  - Strive for utilitarianism by providing the greatest good for the greatest number in an equitable way. Military medical personnel need to adhere to their role under the law of war and avoid blurring the lines between medical care and combatant roles.

- **Understanding funding**, because operational planning requires a sound understanding of funding streams and the legal authorities that govern use of each. Judge Advocate General guidance may be needed. Common funding streams used in military medical operations include:
  - Humanitarian Civic Assistance (HCA) funds (used to care for host-nation patients in authorized HCA activities).
  - Overseas Humanitarian Disaster Assistance and Civic Aid. These funds must benefit host-nation civilians, not militaries.
  - Commanders Emergency Relief Funds. Operational funding that is used for humanitarian purposes as part of combat or stability operations.

Global Health: Systems and Principles in Developing Countries

Humanitarian medical activities require at least a basic understanding of healthcare systems in developing countries. There are many similarities between systems in developing countries, usually related to WHO programs that are implemented to provide low-cost, high-impact solutions to the health problems of the poor.

- Developing countries provide care through a hierarchal, bureaucratic government system commonly referred to as the MoH.
  - Primary care is based on MoH geographic sectors.
  - Thorough coordination with local-sector health leadership is generally required.
  - The hierarchy of authority flows from the central MoH to the regional office, and then to local health workers.
  - Unless an activity is vetted by "higher headquarters," local MoH workers may be reluctant to support the activity, even if they are actually interested in the project.
  - Most developing countries have echelons of care that go from small rural clinics to larger clinics, to small local hospitals, to regional hospitals, to large teaching hospitals.
  - Although MoH doctrine may support the idea of patient movement to higher levels of care, the capacity is frequently lacking.

- Primary care is usually less "doctor-centric" in developing countries.
  - Local MoH care is frequently delivered primarily by nurses, who provide preventive services and a limited number of curative services.
  - Lay health workers (sometimes called "promoters") may work under the direction of MoH nurses.
  - In some countries, lay nurse midwives provide most rural obstetric care. Helping Babies Breathe is a training program from the American Academy of Pediatrics that is aimed at improving the capacity of rural midwives to resuscitate newborns.
- Most MoH systems in developing countries rely on part-time physician support.
  - Newly trained physicians provide "social service" time in underserved areas prior to going on to private practice or specialization.
  - Most do "sick call" for a few hours in the morning for the MoH, but make most of their income through private practice in the evenings.
  - Military physicians do not work for the MoH, but frequently have similar pay schemes and also tend to "moonlight" in private practice.
  - Medications and supplies left behind by US medical teams to aid the local populace may be diverted or misused unless they are delivered into trusted hands. Donations should generally only be given to the appropriate MoH personnel that can legally accept them and take responsibility for the use of the medications or other items. Donations typically require formal paperwork and should be cleared by the responsible US commander or legal authority prior to transfer.
  - Depending on the population being served and the cultural context, local physicians' motivations may not mirror those of US-based physicians.
- Medical systems in developing countries tend to provide care through WHO treatment protocols. They are:
  - Used to standardize and simplify treatments for health workers with limited medical training.

    - Evidence-based and provide care through syndromic empiric treatment.
        - Identifying the syndrome, such as diarrhea or fever and cough, is sufficient to provide treatment.
        - Treatments rely on inexpensive, no-frills medications when needed.
- The most commonly used pediatric WHO protocol is the Integrated Management of Childhood Illness, which:
    - Focuses on children less than 5 years old and the most common causes of mortality in developing countries.
    - Stresses assessing all ill children for preventive medicine needs, such as vaccines and nutritional problems, in addition to providing curative care.

Classification of Medical Humanitarian Operations

US Military Operations

- Civil military operations: military operations that support civil society.
- HCA: operations that involve a component of US military readiness training. HCA operations must:
    - increase the operational readiness of US forces, and
    - improve security for the host nation and the US, or contribute to the economic and social welfare of the host nation.
        - Medical HCA generally consists of short-term exercises that provide direct care to local populations. These may include local civilian or military medical personnel.
        - Engineering HCA may involve construction or renovation of small health facilities.
- Humanitarian Assistance Disaster Relief: includes foreign disaster relief and a variety of programs that primarily benefit host nation civilians, including:
    - disaster preparation (capacity-building programs),
    - humanitarian demining program (training local personnel to handle injuries related to mines and unexploded ordinance),
    - excess (nonlethal) property donation program (surplus military items, including medical equipment, may be donated), and

  - The Denton Program ("Space A" military transportation of humanitarian supplies).
- Medical Civil Action Patrols (MEDCAPs): catchall for medical care provided to rural civilian populations in short-term operations. Medical readiness training exercises are similar programs in the US Southern Command area of responsibility.
- Ad hoc military medical activities can be authorized under a variety of settings.

Nonmilitary Operations

Nonmilitary organizations define "humanitarian operations" differently than the DoD.

- The United States Agency for International Development distinguishes between long-term development and humanitarian operations.
  - Long-term projects are intended to improve health, governance, economic development, and education.
  - Humanitarian operations are only those activities that support acute needs, such as disaster response. The US Agency for International Development Office of Foreign Disaster Assistance takes the lead.
- NGOs include thousands of organizations that operate in the humanitarian community.
  - NGOs have a wide variety of capacities, motivations, and specialty niches.
  - Each should subscribe to a set of ethical principles (see the Sphere Project at http://www.sphereproject.org/handbook/).
  - NGOs act strictly for humanitarian purposes and aspire to complete political neutrality.

Humanitarian Activities in Specific Scenarios

- Humanitarian medical activities during combat operations:
  - Must account for the specific tactical situation and take a backseat to combat operations when necessary.
  - Must conform to the theater MEDROEs. These:
    - generally allow military medical personnel to respond to situations where life, limb, or eyesight of civilians is acutely threatened;

        - must pose no significant increase in risk to US and friendly military security and have no significant impact on medical support to the force; and
        - intend to allow response for acute, emergent conditions, **not** chronic, life-threatening conditions, such as heart disease, cancer, or chronic infections (eg, tuberculosis or human immunodeficiency virus).
    - Must ensure that actions will be sustainable by the host nation after stabilization.
    - Allow for combat medics to be trained for "Band-Aid ops," providing care for minor injuries and illnesses of local civilians that they may encounter (eg, providing oral rehydration packets or over-the-counter pain medications and cleaning and bandaging minor wounds).

Humanitarian Operations in Support of Counterinsurgency Operations

- These are primarily intended to get the majority of the population to reject the insurgents and support the host-nation government.
- Protecting the population from insurgents and restoring basic services (including medical and public health systems) are key components of these operations.
- Medical activities are sometimes viewed as a means to win "hearts and minds." Although they may influence hearts, unless they demonstrate host-nation competence, medical activities may not help win minds.
- Legitimizing the host-nation government is paramount in counterinsurgency operations.
    - Host-nation forces and government services should be the face of any humanitarian operations and be credited with any good that results.
    - Any action that puts host-nation institutions in a bad light, such as providing a higher standard of care than the local health system, may be counterproductive.
    - Simple medical and public health activities that the local forces can execute well may assist with building rapport with the civilian population. Examples include:

        - Helping host-nation medics set up a simple, school-based community education program (tooth brushing, hand washing etc).
        - Helping host-nation military medical personnel improve their capacity to respond to civilian trauma.
- Tactical commanders may request that medical personnel evaluate and treat specific children.
    - Each situation is different and requires thoughtful guidance to the commander.
    - Evaluate the child, specifying up front that a cure or treatment may be impossible, repeating phrases like "no promises" often.
    - Explore all possible solutions allowable under theater MEDROE.
    - As long as expectations are carefully managed, a compassionate evaluation and explanation of the child's condition will be well received.
- Medical activities that directly support intelligence operations should be avoided.
    - The senior medical advisor, such as the brigade or battalion surgeon, should help the commander understand second- and third-order effects of medical activities, such as:
        - loss of trust when medical activities are not sustained, and
        - risk to patients and medical personnel that participate.
    - A line must be drawn between any medical activities and intelligence or military purposes.
    - Medical personnel, including enlisted medics, should only engage in activities that are consistent with their noncombatant role.

Humanitarian Medical Support for Stability Operations

- Doctrine lists restoration of essential services, including public health systems, as a primary goal.
    - Planning methodology for restoration or improvement of host-nation essential services is a gap analysis, which requires assessment of current medical and public health needs **and** the existing capacity to meet those needs.

        - Gaps can be categorized using the DOTMLPF format: Doctrine, Organization, Training, Materiel (equipment and supplies), Leadership, Personnel, and Financing.
        - Training host-nation personnel is usually the biggest "bang for the capacity-building buck."
        - Training alone will not raise capacity if other needs, such as equipment, are not addressed.
        - For sustainment, host-nation leadership must be on board and address organizational and long-term financing issues.
- Building health facilities may be part of stability operations.
    - These must be fully vetted by host-nation health leadership.
    - Staffing, equipping, and logistic sustainment of the facility must be considered up front, not after the fact.
    - It may be better to renovate or enlarge an existing healthcare facility that is already staffed and sustained by the host nation, since it is already accepted by the local population.
    - Commanders' medical advisors, such as field or command surgeons, should be involved with the development of medical infrastructure programs. They may:
        - Liaise with host-nation medical authorities or providers to ensure they are fully on board and have a voice in the project.
        - Provide medical subject-matter expertise to planners and engineers.

Mass Migration Events

Historically, the US military has been tasked with responding to mass migration events. The main mission for the forces assigned is providing for a large displaced population, and primarily involves logistics, security, medical, and engineering aspects. The goal is to keep the population safe and healthy until a solution can be worked out.

- Medical personnel in mass migration focus on:
    - public health and preventive medicine,
    - primary care services to a diverse population that is likely to be medically fragile and afflicted by diseases of poverty and acute and chronic illnesses, and

  - some tertiary care services for seriously ill and injured migrants.
- Patient movement beyond the camp setting may not be possible due to political considerations.
- Logistics
  - Start with a complete census of migrants, with demographic breakdown into age and sex groups.
  - Adequate food, water, and shelter requirements, according to international standards are:
    - Food: 2,100 kcals of culturally acceptable food per migrant.
    - Water: minimum of 4 L/day/migrant to stay alive, 20 to 30 L/day for cooking, cleaning, and washing.
    - Shelter: 3.5 to 4 m^2 below roof (tarps) and 30 m^2/person for total camp space.
  - Hygiene requirements: 1 latrine per 30 migrants. Adequate washing areas.
  - WHO international emergency health kits can provide medical supplies to meet the primary care needs of 10,000 migrants for 3 months.
    - Kits may be ordered with or without a malaria treatment module.
    - Modules are also available for postexposure prophylaxis following sexual assault.
  - Security: separate unaccompanied children and provide care. Family units should be kept intact, but single men should be separated to deter acts of violence against women and children in competition for resources.
- Medical care should follow international standards using WHO-style primary care and health protocols. See the end of the chapter for references.
  - Combat medics fill roles traditionally provided by village nurses and health promoters in WHO-style medical care.
  - Small, rudimentary health dispensaries are located near camps.
  - Caregivers need to be prepared for pediatric, obstetric, and elderly patients.

  - Tertiary care services will be provided by a deployed military field hospital. Both the Army and the Air Force have humanitarian medical packages for field hospitals to cover the needs of children and obstetrics.
- See Chapter 29, Infectious Diseases, for a review of common medical problems encountered during large-scale humanitarian crises.

Humanitarian Activities During Training and Exercises

- Humanitarian activities that take place during training and exercises usually fall under the HCA program.
- Large, land-based exercises, such as Cobra Gold (Thailand), Balikatan (the Philippines), or New/Beyond the Horizons (Latin America and Caribbean) are planned years in advance.
  - These exercises are usually bilateral or multilateral, with the host nation and other nations participating.
  - Medical support consists primarily of short-term medical clinics. Some capacity-building training is possible. Components of military field hospitals may also be deployed.
  - Local health workers can be employed to assist.
- Navy sea-based operations are similar, with the exception that they involve deployment of a hospital or other ships and travel from port to port.
  - These offer more surgical capability than land-based exercises, and operating rooms are brought with the ship. The focus is on high-impact surgeries with minimal long-term follow up.
  - Efforts are being made to increase the capacity-building focus during these missions (eg, using these as a platform for training courses and disaster exercises).
  - Predeployment planning using needs assessment methodology and ensuring the full support of the host-nation medical community and leadership is key to success.
- Surgical stand-alone exercises
  - These provide both a service to the host nation and training for US military surgical residents and staff.
  - Surgical stand-alone exercises are ongoing programs that work in host-nation hospitals.

- US surgeons learn and practice techniques that are important wartime skills.
- Participants practice using the equipment that is used in deployable field hospitals.
- The host nation benefits by decreasing the backlog of indigent surgical care patients.
- Pediatric surgical procedures are a common focus of these programs.

Short-Term Medical Civil Action Program Clinics

- MEDCAP clinics are short-term ad hoc clinics. They have generally fallen out of favor in most recent counterinsurgency operations.
- These activities are controversial; many weaknesses have been noted over the years. Documented problems with some MEDCAPs have included:
  - undermining local health systems,
  - lack of coordination with health systems to provide follow-on care,
  - use of medications that are not used locally,
  - lack of sufficient expertise in local health conditions,
  - insufficient focus on public health,
  - a lack of long-term benefits, and
  - loss of trust when expectations are raised and then not sustained.
- Adequate preparation, planning, and coordination, as well as following sound execution principles, can mitigate the above weaknesses and maximize the benefit to host-nation participants.
  - Preparation focuses on understanding the epidemiology of local health conditions and the health system, cultural aspects, and roles of each team member.
  - Planning involves several factors.
    - Team selection: The team should be selected based on a needs assessment.
      - Most MEDCAPs will serve a disproportionate number of children and women.
      - Dental and optometry services are also helpful, if available.

- Caregivers are public health and preventive medicine practitioners.
- Veterinary services are sometimes included. Improving the health of agricultural animals can be extremely helpful in some situations.

- Site selection: Security is the first determinant in site selection. When possible, work areas should be directed by host-nation health officials.
  - Support for DoD and other US government objectives may influence the area of operations or specific worksites.
  - Match team capability to the worksite. A typical MEDCAP team can provide care for up to 500 patients per day, and it can be easily overwhelmed by large numbers of patients in urban areas.
- Formulary: If possible, the formulary should mirror local health services. Also, consider the WHO essential formulary and the WHO international emergency health kits for guidance.
  - Invest in preventive services, like toothbrushes, vitamin A, and dewormers.
  - Let host-nation personnel provide vaccines to ensure they fit with national programs.
  - Stock no-frills, inexpensive antibiotics, pain relievers, medications for skin conditions, and allergy and acute asthma medications.
  - Dental medications, including local anesthetic, should be included.
  - Some medications and equipment should be provided for urgent needs (epinephrine, injectable antibiotics, intravenous fluids, etc).
  - Generally do **not** provide medications for chronic conditions. Treatment that cannot be sustained should not be begun.
  - Stock oral rehydration packets.
  - There is no requirement to provide cough and cold medications to young children.
  - Children do not necessarily need liquid medications; crushed pills may suffice in many situations.

        - First do no harm: do not provide large amounts of dangerous medications.
    - Coordination: Unless the security situation does not allow it, ensure that the host-nation health system is fully supported and involved up front; it is their country and their population, a respectful attitude and desire to support the local system is paramount.
        - A good strategy is to use the MEDCAP as a "magnet" to attract the local population and facilitate host-nation public health programs.
        - Plan to work side by side with local health workers. Support their needs and value their time investment.
        - Ensure that records of patient encounters and surveillance data will be gathered in accordance with host-nation norms.
        - Plan with the host nation for referrals to higher echelons of care, follow-on care, and chronic care needs.
        - Coordinate for capacity-building activities that will support local needs (eg, continuing education activities or mass casualty exercises).
        - Any planned surgical services should be coordinated with host-nation health authorities based on population needs and must include a plan for any needed follow on postoperative care.
        - Ensure that emergency evacuation plans are prepared for moving US and friendly forces that may become injured during the MEDCAP.
- Conducting a MEDCAP
    - Worksite set-up should provide security and a logical patient flow.
        - Maintain controlled entry and exit points.
        - If possible, have host-nation security personnel manage crowds and staff the entry and exit points.
        - A medical person should periodically "cruise the fence-line," observing the crowd for seriously ill patients.
        - Provide water and shade for waiting patients if lines are long.

- Most patients will first go to a large area for community education and other preventive services. Have host-nation personnel direct and provide most preventive services.
- Patients will then go to the triage area. Seriously ill patients can bypass preventive services, while healthy school-age children may leave directly from the preventive services area if they do not need medical or dental care.
  - Host-nation personnel are frequently better suited than US personnel to take the patient's chief complaint and record the needed demographics.
  - Patients then proceed to medical, dental, and optometric stations, as needed.
  - Patients take scripts to the pharmacy area to collect medications.
  - After pharmacy, patients proceed directly to the controlled exit point to leave.
  - Security personnel and local volunteers assist with directing patients to various stations within the worksite.

- MEDCAP medical care
  - Local health personnel and school officials should be asked to bring any seriously ill or injured children directly to the medical facility for evaluation.
  - Most children will have no significant illness, especially older children.
  - Focus on infants and toddlers. Rely on physical examination and "gut" empirical evaluation and treatment in most situations. Labs and radiographs are usually not available.
  - Providers may have 5 minutes or less to evaluate most children.
  - Common conditions include minor wounds, burns, and skin conditions, as well as upper respiratory and diarrheal infections.
  - "Exotic, tropical" infections are usually relatively uncommon, even in endemic areas, but the healthcare team should be prepared to treat and evaluate diseases

that are reasonably possible. If malaria is prevalent, the team must ensure it is prepared to treat according to the local standard of care.

- Consider keeping a small amount of funds in reserve to purchase local medications that cannot be anticipated.
- There is no requirement for "everyone to get something." Patients can be given vitamins, toothbrushes, and preventive medicine items up front.
- It is best to dispense medications only in the designated pharmacy area, not at the clinical work area.
  - This prevents patients from observing which "stories" are more likely to receive medications.
  - This also facilitates better education about medication without bogging down the clinical providers.
  - The exception is preventive medications, such as dewormers and vitamins, that can be provided in the preventive medicine area prior to reaching medical treatment areas.
  - Only provide medications that are reasonably safe and in safe amounts.

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Appendix A

RESOURCES FOR DEPLOYED PHYSICIANS CARING FOR CHILDREN

The authors and editors of this book are keenly aware that the majority of pediatric healthcare delivered by US military medical personnel in hostile or austere environments is not in a hospital setting. Even the limited resources of a Role 3 facility like a combat support hospital seem lavish in comparison to the equipment, supplies, and medications available to a Role 1 or 2 provider. While this text focuses on applying hospital resources to critically ill and injured children, we wanted to support the efforts to care for children in more resource-constrained environments.

The following list gives medical providers additional clinical, administrative, and doctrinal resources to support decision-making in a deployed or austere environment. The clinical resources draw from a vast body of literature but focus principally on World Health Organization and nongovernmental organization standards and treatment protocols. Developed on a solid foundation of clinical experience and research, these documents are invaluable sources of internationally accepted best practices for both inpatient and outpatient clinical settings with limited resources. They also provide a model of minimum standards of care that developing nations aspire to and deployed military forces may emulate when seeking to provide contextually appropriate medical care that is consistent with (and does not undermine) local health systems.

The military medicine resources provided draw from the robust clinical experience of more than a decade at war. Spanning the spectrum of care from the point of injury to the Role 3 facility, these references emphasize prehospital trauma care as well as the inpatient management of critical care patients. Written with a

solid understanding of the capabilities available to the deployed clinician, these resources reflect the needs and daily realities for deployed medical teams.

Disaster response remains one of the most common contingency operations executed by the Department of Defense. As such, commanders, clinicians, and medical planners must be well versed in both international standards to which the United States subscribes and the doctrinal underpinnings of both the Department of Defense and Department of State responses. The works cited in this list represent how the military plans and executes foreign disaster assistance missions and reflect recent emphasis on enhanced coordination at the interagency and intergovernmental levels as well as with nongovernmental organizations. The military publications represent a rapidly evolving body of doctrine. The reader is advised to seek out new and expanded publications.

Medical Care in Resource-Limited Settings

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Military Medicine

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The US Army has developed three specialty augmentation sets to support hospital-based medical operations for a population of 10,000 people for 10 days in humanitarian assistance/disaster relief operations. They include a pediatric augmentation set (625A) and a surgical set (624A), as well as an adult set (623A), which specifically includes items to care for the chronically ill and elderly. All the sets are "pull items" initially, and then demand supported.

International Guidelines and Online Resources for Disaster Response

The Sphere Project. *The Sphere Handbook: Humanitarian Charter and Minimum Standards for Disaster Response*. Geneva, Switzerland: The Sphere Project; 2011. http://www.sphereproject.org. Accessed January 9, 2015.

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Appendix C

COMPREHENSIVE PEDIATRIC EQUIPMENT SIZING

Comprehensive Pediatric Equipment Sizing

Age / Weight	Mask Size for BVM	Oral/Nasopharyngeal Airways	Laryngeal Mask Airway	Laryngoscope Blade	Endotracheal Tube (Cuff or Not)	Tracheostomy Tube (ID mm)	Suction Catheter
Premature infant (< 3 kg)	0–1 (premie–NBN)	Premie (40 mm)/12 F	1	0 straight	2.5–3.0 uncuffed	2.5	5 F
Newborn (< 28 days; ≥ 3 kg)	0–1 (premie–NBN)	Premature infant (40–50 mm)/ 14 F	1	0–1 straight	3.0–3.5 uncuffed 6 F stylet	3.0–3.5	6 F
Infant (1 month–1 y; 4–10 kg)	1–2 (NBN–infant)	Infant–small (50–60 mm)/ 14–16 F	1–1.5	1 straight	3.5–4.0 uncuffed 6 F stylet	3.5–4.0	8 F
Toddler (1–2 y; 10–13 kg)	2 (infant)	Small (60 mm)/18–20 F	1.5–2	1–2 straight	4.0–4.5 consider cuffed 8 F stylet	4.0–4.5	8–10 F
Preschool (3–5 y; 13–18 kg)	3 (infant–child)	Small–medium (60–70 mm)/22 F	2	2 straight or curved	4.5–5.0 consider cuffed 8 F stylet	5.0	10 F
School age (6–9 y) 18–25 kg	3–4 (child–small adult)	Medium (70–80 mm)/ 24–26 F	2.5–3	2 straight or 2–3 curved	5.5–6.0 cuffed 8 F stylet	5.5	10–12 F
School age (10–12 y) 25–40 kg	4 (small adult)	Medium-large (80 mm)/ 26–30 F	3–4	2–3 straight 3 curved	6.0–6.5 cuffed 8–14 F stylet	6.0–6.5	12 F
Adolescent (13–18 y) > 40 kg	4–5 (small adult–adult)	Large (80–100 mm)/ > 30 F	3–5	3 straight or curved	≥ 7.0 cuffed 14 F stylet	7.0–9.0	14 F

BP: blood pressure, BVM: bag valve mask, ET: endotracheal, F: French, ID: internal diameter, IJ: internal jugular, IV: intravenous, NBN: newborn, NG: nasogastric, OG: orogastric, UAC: uterine artery catheter, UCV: uterine vein catheter

Age / Weight	Chest Tube	BP Cuff Bladder Width/Length	Peripheral IV Catheter	Central Line *(If between sizes chose the smaller line)*	Arterial Line Peripheral/Central	Nasogastric Tube	Foley Catheter
Premature infant (< 3 kg)	8–10 F	2.5–4.5 cm/ 5 cm–9 cm	24 g	5 F UVC, 5 F feeding tube, or central 3–4 F (5–8 cm)	5 F UAC or 5 F Feeding tube as UAC	5 F	5 F
Newborn (< 28 days; ≥ 3 kg)	10–12 F	2.5–4.5 cm/ 5 cm–9 cm	24 g	5 F UVC, 5 F feeding tube, or central 3–4 F (5–8 cm)	2.5 F 2.5 cm or 24 g IV/ 5 F UAC or 2.5–3 F 5 cm femoral	5–8 F	6 F
Infant (1 m–1 y; 4–10 kg)	10–12 F	4–6 cm/ 11.5–18.5 cm	24–22 g	3–4 F 8–12 cm or 20 g 12 cm Pediatric IJ kit	2.5 F 2.5 cm or 24 g IV/ 18 g or 3–3.5 F 5 cm	8–12 F	6–8 F
Toddler (1–2 y; 10–13 kg)	14–20 F	4–6 cm/ 11.5–18.5 cm	24–22 g	4 F 8–12 cm or 20 g 12 cm Pediatric IJ kit	2.5 F 2.5 cm or 22 g IV/ 18 g or 3.5–4 F 5 cm	12 F	8–10 F
Preschool (3–5 y; 13–18 kg)	18–24 F	7.5–9 cm/ 17–19 cm	22–20 g	4–5 F 8–12 cm	22 g IV/18 g or 4–4.5 F	12–14 F	10–12 F
School age (6–9 y) 18–25 kg	20–26 F	7–9.5 cm/ 17–19 cm	20 g	5–6 F 8–12 cm	22 g IV/16 g or 5 F	14–16 F	12–14 F
School age (10–12 y; 25–40 kg)	26–32 F	7–9.5 cm/ 17–19 cm or >9.5 cm/ 22–26 cm	20–18 g	5–6 F 8–12 cm	22 g IV/16 g or 5 F	16 F	14 F
Adolescent (13–18 y; > 40 kg)	> 32 F	>9.5 cm/ 22–26 cm	20–16 g	6–7 F 12–15 cm adult triple lumen	22–20 g IV/16–14 g or 5–6 F	16–18 F	14–18 F

Rules of thumb: (1) depth ET tube at lip = 3 × ET tube size; (2) OG, NG, and Foley size = 2 × ET tube size; (3) chest tube size = 4 × ET tube size; (4) tracheostomy tube ID = age (y)/3 + 3.5

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Colonel Kevin Creamer graduated from the Uniformed Services University of the Health Sciences and completed his pediatric residency at Tripler Army Medical Center. After 3 years of general pediatric practice at the 121st Hospital in Korea and Madigan Army Medical Center, Washington, Dr Creamer returned to train in critical care at the Medical College of Georgia. He subsequently served as the medical director of the pediatric intensive care units at Tripler Army Medical Center, Hawaii, and Walter Reed Army Medical Center, Washington, DC, where he finished his career as the chief of pediatric inpatient services and the pediatric subspecialty consultant to the Army Surgeon General. Dr Creamer's interests include pediatric resuscitation and just-in-time education for deploying medical providers to hostile and austere environments. His team's first project, the Hostile Environments Life-Saving Pediatrics (HELP) CD, was circulated annually to thousands of triservice deploying medical personnel. It included the necessary video presentations, brief handouts, and weblinks to facilitate care for critically ill and injured children by nonpediatric providers. Kevin also created and served as the medical director of the web-based PICU. consult service, which fielded hundreds of critical care consults from Iraq and Afghanistan. His latest projects have been serving as author and editor of the original and subsequent editions of *Pediatric Surgery and Medicine for Hostile Environments*. Dr Creamer is board certified in pediatrics and pediatric critical



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ABBREVIATIONS AND ACRONYMS

A
ABC: airway, breathing, and circulation
AC/A: accommodative convergence to accommodation
ADH: antidiuretic hormone
AE: aeromedical evacuation
AMP: ampicillin
APSA: American Pediatric Surgical Association
aPTT: activated partial thromboplastin time
ATLS: Advanced Trauma Life Support
AV: arteriovenous
AVM: arteriovenous malformation

B
BLS: basic life support
BP: blood pressure
bpm: beats per minute
BSA: body surface area
BUN: blood urea nitrogen
BVM: bag-valve-mask
BWt: body weight

C
CAR: cabin altitude restriction
CBC: complete blood count
CBRNE: chemical, biological, radiological, nuclear, and explosive
CCATT: critical care air transport team
CHF: congestive heart failure
ClCr: creatinine clearance
CMR: crude mortality rate
CMV: continuous mandatory ventilation
CMV: cytomegalovirus
CNS: central nervous system
CO_2: carbon dioxide
CPAP: continuous positive airway pressure

CPP: cerebral perfusion pressure
CPR: cardiopulmonary resuscitation
CRP: C-reactive protein
CSF: cerebrospinal fluid
CT: computed tomography
CV: cardiovascular
CVC: central venous catheter
CVP: central venous pressure

D
D_5W: 5% dextrose in water
$D_{10}W$: 10% dextrose in water
$D_{25}W$: 25% dextrose in water
DIC: disseminated intravascular coagulation
DKA: diabetic ketoacidosis
DM1: diabetes mellitus type 1
DM2: diabetes mellitus type 2
DNA: deoxyribonucleic acid
DoD: Department of Defense
DTPA: diethylenetriaminepentaacetic acid

E
EA: esophageal atresia
ECG: electrocardiogram
ECG: electrocardiography
EDTA: ethylenediaminetetraacetic acid
EEG: electroencephalogram
eGFR: estimated glomerular filtration rate
ENT: ear, nose, and throat
ERCP: endoscopic retrograde cholangiopancreatography
ESR: erythrocyte sedimentation rate
ET: endotracheal
ETT: endotracheal tube
EVD: extraventricular drain

F
FAST: focused assessment with sonography for trauma
FDR: foreign disaster response
FFP: fresh frozen plasma

FiO_2: fraction of inspired oxygen
Fr: French size
FS: fractional shortening

G
GABHS: group A β-hemolytic streptococci
GCS: Glasgow Coma Scale
GI: gastrointestinal
GN: glomerulonephritis

H
HCT: hematocrit
Hgb: hemoglobin
Hib: *Haemophilus influenzae* type B
HIV: human immunodeficiency virus
HPS: hypertrophic pyloric stenosis
HR: heart rate
HSV: herpes simplex virus

I
ICP: intracranial pressure
ICU: intensive care unit
IM: intramuscular
IMV: intermittent mandatory ventilation
IO: intraosseous
IOP: intraocular pressure
ITP: idiopathic thrombocytopenic purpura
ITP: immune thrombocytopenic purpura
IU: international units
IV: intravenous
IVC: inferior vena cava
IVIG: intravenous immunoglobulin

L
LDH: lactate dehydrogenase
LPM: liters per minute
LR: lactated Ringer's
LV: left ventricular

M
MAP: mean arterial pressure
MASCAL: mass casualty
MCI: mass casualty incident
MCV: mean corpuscular volume
MEDROE: medical rules of engagement
MMF: maxillary-mandibular fixation
MRI: magnetic resonance imaging
MRSA: methicillin-resistant *Staphylococcus aureus*
MT: massive transfusion
MTF: medical treatment facility
MUAC: mid-upper arm circumference

N
NG: nasogastric
NPH: neutral protamine Hagedorn
NS: normal saline
NSAID: nonsteroidal antiinflammatory

O
OFDA: Office of Foreign Disaster Assistance
ORS: oral rehydration solution

P
PALS: pediatric advanced life support
PaO_2: partial pressure of oxygen in arterial blood
PC: pressure control
PCA: patient-controlled analgesia
pCO_2: partial pressure of carbon dioxide
PCR: polymerase chain reaction
PEEP: positive end expiratory pressure
PGE1: prostaglandin
PIP: peak inspiratory pressure
PMRC: patient movement requirements center
PO: per os
P_{osm}: plasma osmolality
PRBC: packed red blood cell
PT: prothrombin time
PTU: propylthiouracil
PVC: premature ventricular contraction

R
RBC: red blood cell
RC: reticulocyte count
RDW: red blood cell distribution width
ROP: retinopathy of prematurity
RSDL: Reactive Skin Decontamination Lotion Kit
RSE: refractory status epilepticus
RSI: rapid sequence intubation
RUG: retrograde urethrogram

S
SAM: severe acute malnutrition
SaO_2: oxygen saturation
SBP: systolic blood pressure
SCH: subconjunctival hemorrhage
$ScvO_2$: central venous oxygen saturation
SE: status epilepticus
SIADH: syndrome of inappropriate antidiuretic hormone
SIPRNet: Secure Internet Protocol Router Network
SJS: Stevens-Johnson syndrome
SPT: suprapubic tube
SQ: subcutaneous
SVR: systemic vascular resistance

T
TB: tuberculosis
TBI: traumatic brain injury
TBSA: total body surface area
TEF: tracheoesophageal fistula
TEG: thromboelastography
TEN: toxic epidermal necrolysis
tid: three times daily
TMP/SMX: trimethoprim-sulfamethoxazole
TPN: total parenteral nutrition
TRAC2ES: TRANSCOM Regulating and Command and Control Evacuation System
TRANSCOM: United States Transportation Command
TXA: tranexamic acid

U
UDT: undescended testicle
UGI: upper gastrointestinal
UPJ: ureteropelvic junction
URI: upper respiratory infection
US: ultrasound
USAF: US Air Force
USAID: United States Agency for International Development
UTI: urinary tract infection
UVC: umbilical vein catheter

V
VACTERL: vertebral defects, anal atresia, cardiac defects, tracheo-esophageal fistula, renal anomalies, and limb
VC: volume control
VF: ventricular fibrillation
Vt: tidal volume
VT: ventricular tachycardia

W
WBC: white blood cell
WHO: World Health Organization

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