Overall Approach to Trauma in the Emergency Department

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Practice Gap

Assessing a child who has sustained a multisystem trauma requires a structured assessment of the airway, breathing, and circulation to promptly identify life-threatening injuries and allow for timely lifesaving interventions. This is followed by a more detailed evaluation of the entire body to evaluate for all injuries.

Objectives

After completing this article, readers should be able to:

1. Identify the steps of the primary and secondary surveys used during evaluation of a child who has sustained trauma.
2. Describe the potential life-threatening injuries that may occur after trauma and their treatment.
3. Understand the evaluation and management of a child who has sustained a significant burn.

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ABBREVIATIONS

ABCs	Airway, Breathing, and Circulation
ATLS®	Advanced Trauma Life Support®
BSA	body surface area
CSF	cerebrospinal fluid
EMS	emergency medical services
FAST	Focused Assessment with Sonography for Trauma
GCS	Glasgow Coma Scale
MVA	motor vehicle accident
TBI	traumatic brain injury

INTRODUCTION

The importance of trauma in children is readily apparent in that injury is the leading cause of death and disability in children from infancy to young adulthood in the United States. Each year, more than 9,000 children die of serious injury, and approximately 8.7 million children require emergency department care for treatment of their injuries. (1) This surpasses all major diseases in children and young adults. Specifically, motor vehicle accidents (MVAs) are 1 of the top 2 causes of death in children of all age groups. Childhood injuries result in costs exceeding $87 billion annually (1) when accounting for direct medical costs as well as costs to the economy, cost of rehabilitation, and costs to the families of children who survive childhood injury but have resultant lifelong disabilities.

Childhood injury is a public health problem that has multiple facets, ranging from injury prevention to rehabilitation and reintegration into society. The American College of Surgeons created the Advanced Trauma Life Support® (ATLS®) course to help train physicians to face these challenges. Implementation of ATLS pathways to the acute care of injured children has had a major effect on survival. Early recognition and treatment of life-threatening injuries significantly increase the survival rate after major trauma. Definitive diagnosis is not immediately important; rather, having a standardized method for an initial assessment and management of a trauma, such as primary and secondary surveys, is critical.

The approach to evaluation and treatment of trauma in children relies heavily on the trauma team and how well the skills of individuals are integrated into a cohesive functioning unit. The team not only consists of emergency department physicians and nurses but may also include surgeons, anesthesiologists, radiographers, assistants, security, and the blood bank and laboratory staff. The trauma team needs to be well organized and have a leader who designates roles clearly, facilitates clear communication and recognizes the strengths of the individual members of the team, and uses the information that he or she receives from team members. The team leader typically stands at the foot of the bed, facilitating observation of the entire team. Individual members are responsible for the airway and breathing, circulation (including cardiopulmonary resuscitation), intravenous access, performing the primary and secondary surveys, speaking to the family or emergency medical services (EMS) personnel, and keeping a thorough and accurate record of the resuscitation. It is also important that at some point a team member communicates with the primary physician so that he or she is aware of the trauma.

In the United States, trauma centers are verified by the American College of Surgeons from level I (comprehensive service) to level V (limited care). The different levels reflect the types of resources available to the trauma center and the number of patients admitted yearly (2)(3):

- A level I trauma center is a comprehensive tertiary care resource center capable of providing care for every aspect of any injury. Level I pediatric trauma centers must admit 200 or more injured children younger than 15 years of age annually.
- A level II trauma center is able to initiate definitive care for all injured patients. Level II pediatric trauma centers must admit 100 or more injured children younger than 15 years of age annually.
- A level III trauma center can provide prompt assessment, resuscitation, surgery, intensive care, and stabilization of injured patients.
- A level IV trauma center can provide ATLS before the transfer of patients to a higher-level trauma center.
- A level V trauma center provides initial evaluation, stabilization, and diagnostic capabilities and prepares patients for transfer to higher levels of care.

Trauma centers can also be given separate adult and pediatric designations depending on the hospital's facilities, and, thus, it is common for a single facility to have multiple designations (ie, level I adult facility and level II pediatric facility). Center designation is developed at a local or state level and is outlined through legislative and/or regulatory activity. However, one never knows what type of trauma may roll through the emergency department doors, or perhaps even occur inside hospital walls. As such, any medical provider who practices in an emergency department, irrespective of the provider's degree of formal training or the official trauma designation of the hospital, should be familiar with the basic tenets of pediatric trauma care.

Although the basic principles of a trauma evaluation and resuscitation are the same for children and adults—namely, a primary survey to identify immediate life-threatening conditions followed by a more thorough secondary survey—there are specific anatomical, physiological, and emotional differences that must be considered when evaluating a child who has sustained a trauma. These differences and their implications are noted with respect to the primary survey in Table 1.

EVALUATING THE PATIENT WITH CHEST, ABDOMINAL, OR MULTISYSTEM TRAUMA

The Primary Survey

The term "golden hour" refers to the critical period early in the care of trauma patients when management is crucial to optimizing the chances of patient survival. To ensure a standard method of assessment, the initial evaluation of a child who has sustained significant trauma has been laid out by the American College of Surgeons in ATLS: a primary survey and resuscitation, followed by a secondary survey. (4) The primary survey is completed rapidly and systematically, with the goal of identifying life-threatening conditions and treating them. Patency of the airway, adequate respiratory effort, circulatory support, and neurologic status are evaluated. During the course of resuscitation, the primary survey is repeatedly reassessed to identify any changes and potential deterioration. Table 2 summarizes the steps of the primary survey and the life-threatening conditions that can be identified at each step. It is crucial to attend to the critical aspects in each step of the primary survey before moving on to the next. Typically, enough information is obtained during the primary survey for the physician to determine whether transfer to a higher-level facility is necessary. Providers should wear personal protective equipment as necessary before initiation of the evaluation and resuscitation of the trauma victim.

TABLE 1. **Anatomical and Physiological Differences Between Children and Adults**

SYSTEM	DIFFERENCE FROM ADULTS	IMPLICATION
Airway	Airway is shorter and narrower Larynx and vocal cords in infants are more anterior Tongue is relatively larger in the oropharynx Epiglottis is long and floppy Narrowest point of the airway is below the cricoid cartilage	Differences in the oropharyngeal anatomy can make intubation more difficult, require different-sized endotracheal tubes (including potential use of uncuffed endotracheal tubes), require a different laryngoscope
Breathing	Infants are obligate nasal breathers The chest wall is more compliant	Nasal obstruction can impede respiratory effort Rib fractures and external signs of trauma may not be present with significant intrathoracic injuries
Circulation	Circulating blood volume is increased (∼70–80 mL/kg)	Children remain normotensive for a longer time despite significant blood loss
Disability	Larger occiputs causing passive flexion of the cervical spine The fulcrum of the spine is higher (located at C2-C3) Less-developed cervical musculature Vertebral bodies have facet joints that are horizontally oriented and anteriorly wedged	Anatomical differences result in different types of head and cervical spine injuries than in adults, even with similar forces
	Cervical segments are hypermobile during flexion	Greater potential for spinal cord injury without radiographic abnormality
	Fontanelles present in infants	More subtle signs of increased intracranial pressure may develop before herniation
Exposure	Proportionally larger body surface area	Hypothermia develops more rapidly
	Smaller body mass	Energy imparted results in a greater force applied per body surface area
	Close proximity of multiple organs	Higher frequency of multiple injuries
Emotional	Long-term emotional sequelae may include personality changes and cognitive handicaps	May be necessary to involve mental health professionals in both the acute care and the rehabilitation of the injured child

Airway Maintenance with Cervical Spine Protection

Airway assessment consists of evaluation of the patency of the airway and the ability of air to pass freely into the lungs. A child who is speaking clearly has an unobstructed airway. Airway evaluation includes inspection for foreign bodies and any facial or tracheal/laryngeal fractures that may potentially compromise the airway. Suctioning the oropharynx may be necessary for a complete evaluation. Signs of upper airway obstruction include stridor, hoarseness, subcutaneous emphysema of the neck, use of accessory muscles, and facial or oropharyngeal burns (see the Burns section later herein). Securing an airway may be accomplished via endotracheal intubation. If endotracheal intubation is unsuccessful, a surgical airway, such as a surgical or needle cricothyroidotomy, should be performed.

While managing the airway, it is crucial to maintain the cervical spine in a neutral position. Although a cervical collar facilitates immobilization, if it must be temporarily removed, a trauma team member must manually stabilize the cervical spine. The chin-lift maneuver, where the mandible is gently lifted from the submental area, or the jaw-thrust maneuver, where the angles of the mandible are manually displaced forward, should be used in place of the head-tilt maneuver, which can exacerbate a cervical spine injury. Children with midline cervical spine tenderness, those who have altered mental status, or those who have sustained severe multisystem trauma require a radiographic evaluation of the cervical spine, which can be obtained after the patient has been stabilized.

Breathing

After ensuring a secure airway, the next step is evaluation of the patient's breathing, specifically, ensuring that adequate oxygenation and ventilation are maintained. The patient's breathing should be observed to ensure appropriate and symmetrical chest rise. The chest wall should be auscultated, palpated, and, if ambient decibel level allows, percussed to evaluate for any abnormalities. Signs of respiratory distress include accessory muscle use, grunting, bradypnea or tachypnea, decreased chest wall movement, shallow respirations, and cyanosis. High-concentration oxygen should be applied, and the patient should be monitored using a pulse oximeter and a capnometer. Respirations can be assisted with bag-mask ventilation before intubation if the respiratory effort is not sufficient. A portable chest radiograph can be obtained and may provide significant information.

TABLE 2. Life-threatening Injuries that May Be Identified on the Primary Survey

SYSTEM	LIFE-THREATENING INJURY	TREATMENT
Airway	Airway obstruction	Endotracheal intubation if possible; if not, needle cricothyroidotomy with jet insufflation or surgical cricothyroidotomy
Breathing	Tension pneumothorax Open pneumothorax Massive hemothorax Flail chest Pulmonary contusion	Needle decompression in second intercostal space Application of occlusive dressing that is secured on 3 sides Placement of chest tube and hemodynamic support Respiratory support, fluid resuscitation, and analgesia Respiratory support
Circulation	Cardiac tamponade	Pericardiocentesis

During the course of the assessment of breathing, several life-threatening conditions that may impair ventilation and require immediate intervention may be identified, as follows (5):

- A tension pneumothorax results when air is trapped in the intrathoracic space without a way to escape. There is resultant ipsilateral lung collapse and subsequent mediastinal and tracheal shift away from the tension pneumothorax. There will be respiratory distress, tachycardia (and eventually hypotension), ipsilateral absence of breath sounds, and possible jugular venous distention (which may be difficult to ascertain on an infant or young child). A tension pneumothorax is a clinical diagnosis and is treated with needle decompression by inserting a needle into the second intercostal space in the midaxillary line. A chest tube will need to be placed after this temporizing measure is completed.
- An open pneumothorax occurs when there is direct communication between the intrathoracic cavity and the external environment (typically due to penetrating trauma) that results in an influx of air through the wound into the intrathoracic cavity with every inspiration. An open pneumothorax is treated by applying an occlusive dressing that is taped on 3 sides, thereby allowing air to leave the chest with expiration but preventing it from entering on inspiration.
- A massive hemothorax occurs when blood accumulates in the intrathoracic cavity, resulting in tachycardia, hypotension, ipsilateral decreased breath sounds, and dullness to percussion. A massive hemothorax requires placement of a chest tube and volume resuscitation.
- Flail chest occurs when trauma results in several contiguous ribs fractured in more than one place. The resultant segment moves paradoxically with respiration, preventing adequate ventilation. Flail chest may be a clinical diagnosis or may be found on chest radiography. It is treated with adequate respiratory support, fluid resuscitation, and analgesia. Flail chest is associated with pulmonary contusions—injury to the underlying lung—that can result in hypoxia and respiratory compromise.

Circulation

After ensuring that there are no immediate life-threatening conditions associated with breathing, the evaluation moves forward to the assessment of the patient's circulatory status. This is accomplished by evaluating the patient's level of consciousness, the presence and quality of pulses, skin color, and blood pressure and identifying any sources of external hemorrhage. Direct pressure is applied to any visibly hemorrhaging area, 2 large-bore intravenous lines are placed (or an intraosseous line if vascular access is difficult to obtain), laboratory work (including type and cross) is obtained, and warm crystalloid fluid resuscitation is initiated, in addition to blood transfusions if necessary. Additional sources of internal hemorrhage should be considered (chest, abdomen, pelvis, and long bones). A normal blood pressure should not be considered reassuring because hypotension secondary to bleeding is a late sign of shock in children and is suggestive of massive blood loss. Children with abdominal trauma presenting in shock should promptly be taken to the operating room to identify the source of hemorrhage.

In addition to a massive hemothorax, the immediate life-threatening condition that may be identified during evaluation of the circulation is cardiac tamponade. Tamponade occurs when blood accumulates rapidly inside the pericardium, restricting normal cardiac activity. Symptoms of tamponade include hypotension, jugular venous distention, and muffled heart sounds, together known as the Beck triad, and presence of a pericardial effusion on ultrasonography (see the secondary survey). A pericardiocentesis can be performed to remove blood; however, surgery will ultimately be required to find and repair any cardiac injury. (5)

Disability

After evaluation of the airway, breathing, and circulation (ABCs), the next step is performing a brief neurologic assessment. This can be accomplished using the Glasgow Coma Scale (GCS) (Table 3), checking the pupils, and, if possible, assessing for any localizing neurologic findings. See the Head Trauma section later herein for further details.

Exposure

It is important to completely undress the patient to allow for a thorough secondary survey; however, preventing hypothermia is crucial. Warmed intravenous fluids should be used, and the ambient temperature in the trauma bay should ensure that the patient stays warm.

A gastric tube should be placed to help decompress the stomach, reduce aspiration risk, and assess for gastrointestinal hemorrhage, and a urinary catheter should be placed to carefully monitor urinary output. Midface trauma and/or suspicion of a cribriform plate fracture are contraindications to placement of a nasogastric tube. Concern for a urethral injury, including visualization of blood at the urethral meatus, ecchymosis in the perineum, or palpation of a high-riding prostate, should prompt a retrograde urethrogram before urinary catheter insertion.

TABLE 3. **Adult and Pediatric Glasgow Coma Scales**

		ADULT	PEDIATRIC
Eye opening	4	Spontaneously	Spontaneously
	3	To speech	To voice
	2	To pain	To pain
	1	No response	No response
Verbal response	5	Oriented	Coos, babbles, interacts
	4	Confused	Irritable, crying
	3	Inappropriate words	Cries to pain
	2	Incomprehensible sounds	Moans
	1	No response	No response
Motor response	6	Follows commands	Spontaneous movement
	5	Localizes pain	Withdraws to touch
	4	Withdraws from pain	Withdraws from pain
	3	Decorticate posturing	Decorticate posturing
	2	Decerebrate posturing	Decerebrate posturing
	1	No response	No response

The Secondary Survey

Once the primary survey has been completed, resuscitation of the injured child has commenced, immediate life-threatening injuries have been treated, and the patient has been stabilized, the secondary survey proceeds. The secondary survey consists of a complete history and physical examination and searching for any injury that may have occurred, no matter how small. The patient's age or clinical condition may preclude them from relaying details of the trauma, so information should be sought from a family member, other witnesses of the trauma, and EMS workers. Important information to obtain about the patient and the clinical scenario can be captured by the mnemonic AMPLE:

- Allergies the patient has
- Medications the patient is on
- Past medical history
- Last time the patient ate
- Events related to the sustained trauma (and any intervention by EMS)

As detailed a mechanism of injury as possible should be sought because important information can be gleaned from even a seemingly trivial statement. If the size of the trauma team allows, an individual can be assigned to speak with the family and/or EMS to obtain information. One should always consider underlying anatomical or pathophysiological processes (eg, Wilms tumor) and nonaccidental trauma if the degree of physical findings is out of proportion to the proposed mechanism.

The complete physical examination involves a head to toe evaluation for any injury, no matter how small, including (but is not limited to) the following (4):

- Evaluation of the head and face for scalp lacerations, suspected skull fractures, signs of ocular trauma, maxillofacial and dental trauma, and reassessment of neurologic status
- Evaluation of the neck for signs of blunt or penetrating trauma and vascular injury
- Evaluation of the cervical spine for signs of injury. Although cervical spine stabilization is part of the primary survey, during the secondary survey further evaluation of the cervical spine is warranted, including radiographic evaluation of the cervical spine if the stability and integrity of the cervical spine cannot be ensured on the clinical examination
- Inspection and palpation of the chest for signs of blunt or penetrating trauma, obtaining a chest radiograph if clinically indicated and not previously obtained

- Inspection and palpation of the abdomen for signs of blunt or penetrating trauma, auscultation of bowel sounds, consideration of a pelvic radiograph to evaluate for a pelvic fracture, and performance of a Focused Assessment with Sonography for Trauma (FAST) examination
- Evaluation of the genital area for signs of trauma, rectal examination (if clinically indicated), evaluation for blood at the urethral meatus
- Inspection and palpation of extremities for signs of blunt or penetrating injury, obtaining imaging of areas of concern, and splinting injuries as clinically indicated. Care should be taken to roll the patient to the side while maintaining cervical spine stabilization so that the back, buttocks, and thoracic and lumbar spine can also be evaluated for signs of trauma
- Evaluation for signs of peripheral neurologic injury as allowed by the clinical condition

Potential life-threatening injuries that can be found during the secondary survey include simple pneumothorax, hemothorax, aortic disruption, tracheobronchial injury, diaphragmatic injury, and esophageal rupture.

The FAST examination is a point-of-care sonographic assessment looking for signs of intra-abdominal and intrathoracic injury. The FAST examination is an invaluable adjunctive tool to the secondary survey as it is performed at the same time as other resuscitative efforts by another member of the trauma team and there is no delay in receiving imaging results because they are interpreted bedside by the trauma team. Sonographic views of the FAST examination include a subxiphoid view of the heart (evaluating for a pericardial effusion), evaluation for blood in the Morison pouch (the potential space between the liver and the kidney), the perisplenic recess, and the retrovesicular area in males and the Douglas pouch (the potential space between the uterus and the rectum) in females. Other adjunctive tools include laboratory work, radiographs, computed tomographic (CT) scans, and an electrocardiogram.

Performance of the secondary survey is crucial to ensuring a comprehensive evaluation of the patient who potentially sustained multisystem trauma. Frequent reassessments of both the primary and secondary surveys are crucial to identify subtle signs of decompensation and ensure that early and appropriate interventions can be undertaken to restabilize the child if necessary.

HEAD AND CENTRAL NERVOUS SYSTEM TRAUMA

Traumatic brain injury (TBI) is a leading cause of death and disability in children in the United States. Children can sustain head and/or central nervous system injury as either part of a multisystem trauma (eg, during an MVA) or as an isolated injury (eg, struck by an object). In addition, nonaccidental trauma must always be considered, especially when there is head trauma in a nonambulatory child or if the story does not make sense given the developmental stage of the child. Younger children are at a higher risk for sustaining head trauma because their heads are proportionally larger than the rest of their bodies and their skull is less protective than that of an adult. In addition, differences in the ratio of the brain to intracranial spaces result in less cushioning of the brain in cerebrospinal fluid (CSF) and, thus, less protection when an accident happens.

Brain injury secondary to trauma can be due to direct trauma between the brain and the internal aspect of the skull (cerebral contusion), shearing forces (diffuse axonal injury), or secondary to intracranial bleeding leading to a sudden increase in intracranial pressure (epidural or subdural hematomas). The Monro-Kellie doctrine states that the total volume of intracranial contents, which normally consists of brain, CSF, and arterial and venous blood, must remain stable because the skull is a nonexpandable container. Injuries causing an epidural or subdural hematoma will ultimately result in increased intracranial pressure once the CSF and intravascular blood has been displaced from the intracranial space by the expanding hematoma. An older child with a subdural or epidural hematoma will present with headaches, vomiting, and altered mental status, whereas an infant may initially present with only a bulging fontanel before more overt signs of an acute increase in intracranial pressure from an intracranial bleed. The Cushing triad (bradycardia, hypertension, and respiratory depression) signifies increased intracranial pressure and impending herniation. On the other hand, hypotension in the setting of head trauma should prompt evaluation for a source of extracranial blood loss.

Evaluation of a child who sustained head trauma, whether in conjunction with multisystem trauma or in isolation, begins with the organized process of the primary survey (the ABCs) as detailed previously herein. Special consideration should be given to the Disability section of the primary survey. Two commonly used assessments of disability include the AVPU scale and the GCS. The AVPU scale assesses whether a child is Awake and whether he or she responds to Verbal stimuli, responds to Pain, or is Unresponsive. The GCS measures 3 components, verbal, motor, and eye responses, and has been slightly modified for pediatrics (Table 3). A GCS score of 13 or greater is usually indicative of a minor TBI, a score of 9 to 12 is considered a moderate TBI, and a score of 8 or less is typically indicative of a severe TBI. Children with a GCS score of 8 or less should be intubated to protect their airway and should undergo head CT and a neurosurgical consultation. A child with a GCS score of 9 to 12 should also undergo head CT and be admitted for neurologic monitoring. Children with a GCS score of 13 or greater may or may not require head imaging. Pupillary examination is also a key aspect of the evaluation of a child's disability. For instance, asymmetrical pupils may be a sign of impending herniation after trauma, and pinpoint pupils may represent an opiate overdose as the cause of decreased responsiveness.

Multiple studies have sought to identify cohorts of children who are at low risk for having sustained a clinically important TBI and, thus, can possibly forego a head CT scan and being exposed to the risks of radiation. These include (but are not limited to) the PECARN (Pediatric Emergency Care Applied Research Network), (6) CATCH (Canadian Assessment of Tomography for Childhood Head injury), (7) and CHALICE (Children's Head injury ALgorithm for the prediction of Important Clinical Events) (8) rules. All of these clinical decision rules use different risk factors to identify low-risk children (Table 4); however, they are all very sensitive, with extremely high negative predictive values. (9) Currently, 1 or more of these rules are typically used when clinicians are faced with a child who sustained head trauma and looks very well on examination.

A concussion is a type of TBI that results from a blow to the head or elsewhere to the body (with force transmitted to the head) that may or may not be followed by loss of consciousness. A concussion can present with a panoply of symptoms, including any of the following: headache, amnesia, dizziness, vomiting, fatigue, vision problems, sensitivity to light or noise, imbalance or gait problems, difficulty concentrating, and emotional lability.

There are standardized assessment tools developed to diagnose concussions to ensure that children are not placed back into a situation that could risk further injury. Although there are varying opinions about what should constitute "cognitive rest" with respect to concussion management, it is widely believed that there should be a period of "physical rest" and a progression of return to play that commences when all concussive symptoms have resolved. The Centers for Disease Control and Prevention has an informative website that provides information to parents, coaches, schools, and practitioners (http://www.cdc.gov/HeadsUp).

Spinal cord injury is comparatively infrequent in children. Injuries to the spinal cord result in a presentation that depends on the exact spinal level (ie, C7 vs L1) and cord location (ie, anterior cord, hemisection of cord) of the injury. The immature spine is significantly more flexible due to a relative laxity of the interspinous ligaments, flat facet joints, and vertebrae that are wedged anteriorly. This flexibility can result in an injury called SCIWORA—Spinal Cord Injury WithOut Radiographic Abnormality—that typically occurs in the cervical region. Recognition of this entity is important because a significant number of spinal cord injuries can have normal cervical spine radiographs. Thus, if a spinal cord injury is suspected based on history or physical examination findings and there are normal cervical spine radiographs, magnetic resonance imaging of the spine should be performed.

BURNS

Burns represent a unique aspect in pediatric trauma. They can occur in conjunction with a larger multisystem trauma (eg, MVA with subsequent fire), which can complicate the resuscitation and lead to higher morbidity; however, they typically occur in isolation as an accidental burn (eg, splash or spill of hot water). It is important to always consider an inflicted burn as due to possible child abuse. Inflicted burns may be patterned, have sharp demarcations including being perfectly circular, spare intertriginous areas, or not be consistent with the mechanism provided.

Assessment of a burn includes determination of the amount of skin involved (body surface area [BSA]) and the depth of the burn. This is typically accomplished using the "rule of nines," which divides the body of an adult or older child into multiples of 9%. The trunk and back are 18% each, the anterior and posterior lower extremities are 9% each, the anterior and posterior upper extremities and head are 4.5% each, and the genital area is 1%. This is slightly modified for infants to account for the comparatively large head. Alternatively, the patient's hand (including fingers) represents approximately 1% BSA.

Burns can be characterized into 3 different depths as follows:

- Superficial burns—red, painful, and do not blister (eg, most sunburns)
- Partial-thickness burns—typically red and swollen, exquisitely painful, appear wet, and are characterized by blistering
- Full-thickness burns—waxy or leathery appearance, are not painful to the touch, and the skin tends to feel dry

Superficial burns are not included when calculating the BSA involved. Recognition that blistering may take time to develop is important because areas initially characterized as a superficial burn may truly be a partial-thickness burn only to develop the blistering several hours later.

TABLE 4. **Comparison of Risk Factors Potentially Necessitating a Head Computed Tomographic Scan in Children after Head Trauma**

RISK FACTOR	CATCH	CHALICE	PECARN
GCS score	<15 (>2 h after injury)	<14 (<15 if <1 y)	<15
Suspected fracture	Yes (suspected open or depressed fracture)	Yes (suspected depressed or penetrating fracture)	Yes (palpable skull fracture [only if <2 y])
Sign of basilar skull fracture	Yes	Yes	Yes (only if >2 y)
Change in mentation	Yes (irritability on examination)	Yes (abnormal drowsiness)	Yes (including not acting normally as per parent if <2 y)
Loss of consciousness	No	Yes (>5 min)	Yes if >5 sec if <2 y, yes if >2 y
Headache	Yes (if worsening)	No	Yes (if severe and >2 y)
Hematoma	Yes (large, boggy)	Yes (any bruise or swelling)	Yes (if nonfrontal and <2 y)
Vomiting	No	Yes (≥3 episodes)	Yes (if >2 y)
Amnesia	No	Yes	No
Concern for nonaccidental trauma	No	Yes	No
Seizure	No	Yes (if no history of epilepsy)	No
Focal neurologic findings	No	Yes	No
Dangerous mechanism of injury	Yes (MVC, fall ≥3 ft or 5 stairs, fall off bicycle without helmet)	Yes (high-speed MVC [>40 mph] as occupant or pedestrian, fall >3 ft, high-speed projectile injury)	Yes (MVC with ejection, death, or rollover; pedestrian or cyclist struck by car; fall >3 ft [<2 y] or >5ft [>2 y]; high-speed projectile injury)

CATCH=Canadian Assessment of Tomography for Childhood Head injury, CHALICE= Children's Head injury ALgorithm for the prediction of Important Clinical Events, GCS=Glasgow Coma Scale, MVC=motor vehicle crash, PECARN=Pediatric Emergency Care Applied Research Network.

Fluid management is crucial in children who have sustained significant burns. In addition to providing maintenance fluid, ongoing fluid losses must be accounted for with fluid resuscitation. One of the commonly used calculations to determine the fluid requirements for the first 24 hours after a significant burn is the Parkland formula: 4 mL/kg × total BSA affected. Half of this fluid is administered in the first 8 hours, the remaining half over the next 16 hours. Maintenance fluid is typically administered as well in younger children. Recently a nomogram has been created to assist in rapid calculation of appropriate volume administration. (10)(11) Other principles of burn management include analgesia, debridement, dressings, and tetanus vaccination.

Other issues to consider when evaluating a patient who has been burned include the possibility of an inhalational burn, as well as exposure to other inhalants from a fire. Signs of an inhalational burn include singed nose hairs, carbonaceous sputum, hoarseness, stridor, drooling, and oropharyngeal edema. Children with facial burns should be monitored closely for progression of an inhalational injury, as the initial symptoms may be subtle. Airway management of a patient who has sustained an inhalational injury can be very difficult and should be handled by a trained specialist. Children who have been in a residential or industrial fire are at risk for both carbon monoxide and cyanide poisoning because these are common byproducts of decomposition of both synthetic and natural substances.

Although many burns can be managed at any medical locale, certain thermal burns are recommended to be treated at a burn center, including (but are not limited to) any full-thickness burn; partial-thickness burns larger than 10% BSA; burns including genitalia, face, hands, feet, or major joints; inhalational injuries; and children in centers without the necessary qualified personnel or equipment. (12)

ORTHOPEDIC TRAUMA

Orthopedic trauma is the most common form of trauma in children and occurs both in the setting of multisystem trauma and, more commonly, in isolation. When evaluating a child who has sustained multisystem trauma, orthopedic considerations include cervical spine stabilization (see previously herein) and evaluation for a pelvic fracture, which, similar to a femur fracture, can lead to significant hemorrhage that may not be easily appreciated on the physical examination. Areas identified during the secondary survey as a concern for fracture or dislocation should be appropriately imaged.

Open fractures, where there is direct communication between the fracture and the external environment, are an orthopedic emergency. An open fracture may be extremely obvious, with bone protruding from the skin, or it may be as subtle as a small break in the skin, which in actuality represents penetration of a fractured bone through the epidermis that has since receded back underneath the skin. In the latter case, excessive bleeding, crepitus, and blood with visible fat globules at the wound site may be indications that the small wound is actually an open fracture. Open fractures require orthopedic consultation, removal of debris and cleaning of any protruding bone with saline, reduction of the fracture, administration of tetanus immunoglobulin and tetanus toxoid as necessary, and prophylactic antibiotic drug therapy.

In addition to open fractures, fractures that result in neurovascular compromise are also orthopedic emergencies. Neurovascular compromise can result from a direct nerve or vascular injury from a displaced fracture or can occur hours or days later due to compartment syndrome. Assessment of motor function, sensation, pulse quality, and capillary refill of an injured extremity are critical parts of the physical examination. Any apparent neurovascular dysfunction should be noted, and if occurring in close proximity to the trauma may necessitate urgent manipulation and reduction.

Compartment syndrome occurs due to increased pressure in a fascial compartment that exceeds venous pressure, compromises circulation, and results in ischemia of nerve and muscle, causing tissue damage. The diagnosis of compartment syndrome should be suspected in a patient who has pain out of proportion to the underlying injury and/or pain on passive stretching of muscles of an affected extremity. Other signs and symptoms, such as paresthesia, paralysis of an extremity, pulselessness, pallor, and poikilothermia, the so-called 5 *P*s of compartment syndrome, are late findings. Compartment syndrome is a true surgical emergency and requires emergent orthopedic consultation and a decompressive fasciotomy.

Summary

- Trauma remains a major cause of morbidity and mortality in children.
- On the basis of some research evidence and consensus, the appropriate method of evaluating a child who has sustained multisystem trauma is using an organized, systematic approach with primary and secondary surveys with the goals of resuscitation, stabilization, and identification and treatment of life-threatening injuries. (4)(5)
- Both multisystem trauma and other forms of seemingly isolated trauma, including head trauma, burns, and orthopedic trauma, should always be carefully evaluated to ensure complete assessment of all injuries, no matter how small. The possibility of nonaccidental trauma should remain on the differential diagnosis of an injured child.
- Based on strong research evidence, it is possible to identify a cohort of children who have sustained head trauma who are at low risk for a significant intracranial injury and can likely forego a computed tomographic scan of the head. (6)(7)(8)
- Fluid management is crucial for children who have sustained significant burns. The Parkland formula can be used to calculate the fluid requirement in conjunction with maintenance fluids.
- It is crucial to ensure communication with the patient's primary physician, whether the child sustained severe multisystem trauma or a simple fracture, because he or she will play a leading role in the ongoing rehabilitation processes and reintroduction of the child back to normal activity.

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PIR Quiz

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1. A pediatric tertiary care hospital has a trauma service with the following characteristics:

   Comprehensive tertiary care resource center
   Can provide care for every aspect of any injury
   Admits 125 children younger than 15 years of age annually for trauma-related injuries

   According to the American College of Surgeons trauma classification system, which of the following represents the trauma service level that is offered by this hospital?

   A. Level I.
   B. Level II.
   C. Level III.
   D. Level IV.
   E. Level V.

2. A 3-year-old child is brought to the emergency department after a high-speed motor vehicle collision. This hospital has a level III pediatric trauma center. The child was properly restrained in the back seat of the car. The car flipped several times before coming to rest on its side. The child has been transported with a cervical collar in place. He has an initial Glasgow Coma Scale score of 8. He has a large hematoma to the forehead, as well as a 4-cm laceration to the left parietal scalp that is oozing blood. His heart rate is 160 beats/min, respiratory rate is 12 breaths/min, blood pressure is 82/55 mm Hg, and pulse oximetry is 91% on room air. He is moving all of his extremities spontaneously. Which of the following issues must be addressed immediately during the primary survey?

   A. Arrange for transfer of the patient to a level I trauma center.
   B. Consult neurosurgery due to the depressed level of consciousness.
   C. Insert an endotracheal tube to protect the airway and assist with breathing.
   D. Order neck radiographs to assess for cervical spine injury.
   E. Repair the laceration to prevent further bleeding.

3. A 12-year-old child sustained a nondisplaced pelvic fracture after a motor vehicle collision and is brought to the emergency department by emergency medical services. After performing the primary survey, the emergency department team is preparing to insert a urinary catheter. The presence of which of the following clinical findings warrants performing a retrograde urethrogram before insertion of the urinary catheter in this patient?

   A. Blood visualized at the urethral meatus.
   B. Liver laceration has also been identified.
   C. The patient has diffuse abdominal pain.
   D. There is a large laceration at the iliac crest.
   E. Urinary catheter placement should be ordered in any obtunded trauma victim.

4. A 6-year-old girl sustained a massive head trauma after a head-on collision between 2 motor vehicles. The patient was an unrestrained passenger. She has a Glasgow Coma Scale score of 3. An endotracheal tube was placed at the scene by the transporting helicopter crew. Her blood pressure on arrival at the emergency department is 140/90 mm Hg, heart rate is 60 beats/min, and pulse oximeter reading on 50% oxygen is 98%. She has a large hematoma involving most of the right parietal region. A computed tomographic scan of the brain is performed, neurosurgery is consulted, and the patient is started on mannitol per the Monro-Kellie doctrine. Which of the following principles is the basis for the Monro-Kellie doctrine?

   A. Arterial blood is at higher pressure than venous blood.
   B. Blood is denser than water.
   C. Hyperventilation causes cerebral vasoconstriction.

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D. Systemic blood pressure must always exceed intracranial pressure.
E. The skull is a nonexpandable container.

5. A 14-year-old boy is brought to the emergency department after sustaining a closed head trauma. The patient was playing soccer at school when he ran into his teammate and his head hit the teammate's shoulder bone. He felt dizzy immediately but had no complaints 5 to 10 minutes after the incident. There is no loss of consciousness, no vomiting, no headaches, and no vision changes. On examination in the emergency department, he is oriented to time, place, and person. There is a small bump over the left parietal area of the skull with no open wounds or hematomas and no depressed skull ridge on palpation. The remainder of his physical examination, including his neurologic examination, is within normal limits. In this patient with traumatic brain injury, which of the following management decisions is based on the primary purpose of the PECARN (Pediatric Emergency Care Applied Research Network), CATCH (Canadian Assessment of Tomography for Childhood Head injury), and CHALICE (Children's Head injury ALgorithm for the prediction of Important Clinical Events) rules?
   A. Assess whether the patient is at risk for posttraumatic learning problems requiring special accommodations at school.
   B. Determine the need for neurosurgical follow-up.
   C. Determine when the patient can return to playing sports.
   D. Forego a computed tomographic scan of the brain.
   E. Predict the need for formal psychological testing.