Chapter 10: Pediatric Trauma

Objectives:

Upon completion of this topic, the participant will be able to:

A. Discuss the unique characteristics of the child as a trauma patient.
   1. Types of injury.
   2. Patterns of injury.
   3. Anatomic and physiologic differences in children as compared with adults.

B. Discuss the primary management of the following critical injuries in children based on the anatomic and physiologic differences as compared with adults.
   1. Airway management.
   2. Shock and maintenance of body heat.
   3. Fluid and electrolyte management.
   4. Medications and dosage.
   5. Cervical spine injuries.
   6. Psychologic support.

C. Discuss the injury patterns associated with the abused child and the elements that lead to the suspicion of child abuse.

D. Discuss the epidemiology of childhood injury and effective strategies for injury prevention in children.

E. Demonstrate in a simulated situation the following procedures for the pediatric trauma victim.
   1. Endotracheal intubation.
   2. Intravenous/intraosseous access.
   3. Fluid and drug administration.
I. Introduction

Nearly 22 million children are injured each year in the United States, representing nearly one in every three in the pediatric age group. Injuries surpass all major diseases in children and young adults making it the most serious health care issue for this population cohort. Encounters with motor vehicles, either as an occupant, a pedestrian, or a cyclist, account for the largest fatally injured group followed by drownings, house fires, and homicide. Falls and vehicular crashes account for almost 80% of all pediatric injuries, although distressingly the number of penetrating injuries is on the rise. Multisystem injury is the rule rather than the exception and therefore all organ systems must be assumed to be injured until proved otherwise. **Children with multisystem injuries can deteriorate rapidly and develop serious complications. Therefore, such patients should be transferred early to a facility capable of managing the child with multisystem injuries.**

The order and priorities of assessment and management of the injured child are the same as in the adult. However, the unique anatomic characteristics of the pediatric population require special consideration in the assessment and management of the pediatric trauma victim.

A. Size and Shape

Because of the smaller body mass of children, the energy from the linear forces from fenders, bumpers, and falls results in a greater force applied per unit body area. This more intense energy is further applied to a body with less fat, less elastic connective tissue, and close proximity of multiple organs. The result is the high frequency of multiple organ injuries seen in the pediatric population.

B. Skeleton

The child's skeleton is incompletely calcified, contains multiple active growth centers, and is more pliable. For these reasons, internal organ damage is frequently noted without overlying bony fracture. For example, rib fractures in the child are uncommon, but pulmonary contusion is common. Other soft tissues of the thorax, the heart, and mediastinal structures may sustain significant damage without evidence of bony injury. The identification of rib fractures in a child suggests the transfer of a massive amount of energy and multiple, serious organ injuries should be suspected.

C. Surface Area

The ratio of a child's body surface area to body volume is highest at birth and diminishes as the child matures. As a result, thermal energy loss becomes a significant stress factor in the child. Hypothermia may develop quickly and complicate the management of the hypotensive pediatric patient.

D. Psychologic Status

Psychologic ramifications of caring for an injured child can present significant challenges. In the very young, emotional instability frequently leads to a regressive
psychologic behavior when stress, pain, or other perceived threats intervene in the child's environment. The child's ability to interact with unfamiliar individuals in strange and difficult situations is limited, making history-taking and cooperative manipulation, especially if it is painful, extremely difficult. The physician who understands these characteristics and is willing to cajole and soothe an injured child is more likely to establish a good rapport. This facilitates comprehensive assessment of the child's psychologic as well as physical injuries.

E. Long-term Effects

A major consideration in dealing with injured children is the effect that injury may have on subsequent growth and development. Unlike the adult, the child must not only recover from the effects of the traumatic event, but also must continue the normal process of growth and maturation. The physiologic and psychologic effects of injury on this process should not be underestimated, particularly in those cases involving long-term function, growth deformity, or abnormal subsequent development. Children sustaining even a minor injury may have prolonged disability in either cerebral function, psychologic adjustment, or organ system disability. Recent evidence suggests that as many as 60% of children who sustain severe multisystem trauma have residual personality changes at one year following hospital discharge, and 50% show cognitive and physical handicaps. Social, affective, and learning disabilities are present in one half of seriously injured children. In addition, childhood injuries have a significant impact on the family structure, with personality and emotional disturbances in two thirds of uninjured siblings. Frequently, a child's injuries impose a strain on the family's marital relationship, including the financial and sometimes employment hardships. Inadequate or inappropriate care in the immediate posttraumatic period may affect not only the child's survival, but perhaps just as importantly, the quality of the child's life for years to come.

F. Equipment

Immediately available equipment of the appropriate size is essential for successful initial management of the injured child. (See Table 5 at the end of this chapter.) The recently available Broselow Pediatric Resuscitation Measuring Tape is an ideal adjunct for rapid determination of weight based on length for appropriate drug doses and equipment size. (See Skill Station IV, Vascular Access and Monitoring.)

II. Airway Management

The primary goal of initial assessment and triage of the injured child is to restore, or maintain, adequate tissue oxygenation. Oxygen delivery is as essential to the injured child as to the adult. The standard principles of airway control, breathing, and circulation are applied to the injured child as they are to the adult. The child's airway is the first priority of assessment.

A. Anatomy

The smaller the child, the greater is the disproportion between the size of the cranium and the midface. This produces a greater propensity for the posterior pharyngeal area to buckle as the relatively larger occiput forces passive flexion of the cervical spine. The child's

3
airway is thus protected by a slightly superior and anterior position of the midface, known as the "sniffing position". Careful attention to maintaining this position while providing maximum protection to the cervical spine is especially important in the obtunded child. Soft tissues in the infant's oropharynx (ie, tongue, tonsils) are relatively large compared with the oral cavity, which may make visualization of the larynx difficult.

A child's larynx has a slightly more antero-caudal angle and is frequently more difficult to visualize for direct cannulation in the slightly head-flexed position assumed by the supine child. The infant's trachea is approximately five centimeters in length and grows to seven centimeters in about 18 months. Failure to appreciate this short length may result in intubation of the right mainstem bronchus, inadequate ventilation, and mechanical injury to the delicate bronchial tree.

B. Management

In a spontaneously breathing child, the airway should be secured by the chin lift or jaw thrust maneuver. After the mouth and oropharynx have been cleared of secretions or debris, supplemental oxygen should be administered. If the patient is unconscious, mechanical methods of maintaining the airway may be necessary.

Before attempts are made to mechanically establish an airway, the child should be oxygenated.

1. Oral airway

The practice of inserting the airway backwards and rotating it 180 degrees is not recommended for the pediatric patient. Trauma with resultant hemorrhage into soft-tissue structures of the oropharynx may occur. The oral airway should be gently inserted directly into the oropharynx. The use of a tongue blade to depress the tongue may be helpful. As in the adult, the oral airway should not be used in the conscious child.

2. Orotracheal intubation

Endotracheal intubation is the most reliable means of ventilating the child with airway compromise. Uncuffed tubes of appropriate size should be used to avoid subglottic edema, ulceration, and disruption of the infant's fragile airway. The smallest area of the child's airway is the cricoid, which forms a natural seal with the endotracheal tube. Therefore, cuffed endotracheal tubes are not needed. A simple technique to gauge the size of the endotracheal tube is to approximate the diameter of the external nares or the child's fifth (small) finger with the tube diameter.

Orotracheal intubation under direct vision with adequate immobilization and protection of the cervical spine is the preferred method of obtaining initial airway control. Nasotracheal intubation should not be performed in children. Nasotracheal intubation requires blind passage around a relatively acute angle in the nasopharynx toward an anterior and cranially located glottis, making intubation by this route difficult. Inadvertent penetration of the cranial vault or damage to nasopharyngeal soft tissues also makes the nasotracheal route for airway control ill-advised.
Once past the glottic opening, the endotracheal tube should be positioned 2.0 to 3.0 cm below the level of the vocal cords and carefully secured in place. Auscultation of both hemithoraces in the axillae should be performed to ensure that right mainstem bronchial intubation has not occurred, and that both sides of the chest are being adequately ventilated. Any movement of the head may result in displacement of the endotracheal tube. Breath sounds should be evaluated periodically to ensure that the tube remains in the appropriate position and to identify the possibility of evolving ventilatory dysfunction.

3. Cricothyroidotomy

Surgical cricothyroidotomy is rarely indicated for the infant or small child, and if absolutely necessary, it should be performed by a surgeon. When airway access and control cannot be accomplished by bag-valve-mask or orotracheal intubation, needle cricothyroidotomy is the preferred method. Needle jet insufflation via the cricothyroid membrane is an appropriate, temporizing technique for oxygenation, but it does not provide adequate ventilation and hypercarbia may occur.

4. Ventilation

Children should be ventilated at a rate of approximately 20 breaths per minute, while infants require 40 breaths per minute. Tidal volumes of 7 to 10 mL per kilogram are appropriate for both infants and children. Although most bag-valve-mask devices for use with pediatric patients are designed to limit the amount of pressure that can be exerted manually on the child's airway, the physician should remember the fragile nature of the immature tracheobronchial tree and alveolae to minimize the potential for iatrogenic bronchoalveolar injury.

The most common acid-base abnormality that develops during pediatric resuscitation is acidosis secondary to hypoventilation. If adequate ventilation and perfusion have been re-established, the injured child should be able to maintain a relatively normal pH. Remember, in the absence of adequate ventilation and perfusion, sodium bicarbonate does not correct the evolving acidosis and may lead to further hypercapnea.

5. Tube thoracostomy

Injuries that disrupt pleural to pleural apposition, eg, hemothorax, pneumothorax, or hemopneumothorax, occur with equal frequency in children as adults with the same physiologic consequences. These injuries are managed with pleural decompression. Chest tubes are obviously of smaller size (see table at the end of this chapter) and are placed into the thoracic cavity by tunneling the tube over the rib above the thoracostomy site.
III. Shock

Every injured child with evidence of hypotension or inadequate organ system perfusion must be evaluated by a surgeon as soon as possible.

A. Recognition

Injury in childhood frequently results in significant blood loss. The increased physiologic reserve of the child allows the maintenance of nearly normal vital signs even in the presence of severe shock. This early state of "compensated" shock may be misleading and may mask a major reduction in circulating blood volume. Tachycardia and poor skin perfusion are the keys to recognizing this problem and to instituting appropriate crystalloid resuscitation.

The primary response to hypovolemia in the child is tachycardia. However, caution must be exercised when monitoring only the child's heart rate because tachycardia also may be caused by pain, fear, and psychologic stress. Blood pressure and indices of adequate organ perfusion, eg, urinary output, should be monitored closely.

Hypotension in the child represents a state of uncompensated shock and indicates severe blood loss and inadequate resuscitation. Changes in vital organ function are outlined in Table 1, Systemic Responses to Blood Loss in the Pediatric patient. Although signs of severe hypovolemic shock may be unmistakable, signs of early hypovolemic shock may be extremely subtle. Careful, repeated evaluation is imperative.

Table 1. Systemic Responses to Blood Loss in the Pediatric Patient

<table>
<thead>
<tr>
<th>Blood Volume Loss</th>
<th>&lt; 25% Blood Volume Loss</th>
<th>25%-45% Blood Volume Loss</th>
<th>&gt;45% Blood Volume Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiac</td>
<td>Weak, thready pulse; increased heart rate</td>
<td>Increased heart rate</td>
<td>Hypotension, tachycardia to bradycardia</td>
</tr>
<tr>
<td>CNS</td>
<td>Lethargic, irritable, confused</td>
<td>Change in level of consciousness, dulled response to pain</td>
<td>Comatose</td>
</tr>
<tr>
<td>Skin</td>
<td>Cool, clammy</td>
<td>Cyanotic, decreased capillary refill, cold extremities</td>
<td>Pale, cold</td>
</tr>
<tr>
<td>Kidneys</td>
<td>Decreased urinary output; increased specific gravity</td>
<td>Minimal urine output</td>
<td>No urinary output</td>
</tr>
</tbody>
</table>

The association of tachycardia, cool extremities, and a systolic blood pressure of less than 70 mm Hg are clear indicators of evolving shock. Early compensated shock may present with normal vital signs. As a rule, a child's blood pressure should be 80 mm Hg plus twice the age in years, and the diastolic pressure should be two thirds of the systolic blood pressure. (See Table 2, Vital Signs.)
Table 2. Vital Signs

<table>
<thead>
<tr>
<th></th>
<th>Pulse Rate (Beats/min)</th>
<th>Blood Pressure (mm Hg)</th>
<th>Respiratory Rate (Breaths/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infant</td>
<td>160</td>
<td>80</td>
<td>40</td>
</tr>
<tr>
<td>Preschool</td>
<td>120</td>
<td>90</td>
<td>30</td>
</tr>
<tr>
<td>Adolescent</td>
<td>100</td>
<td>100</td>
<td>20</td>
</tr>
</tbody>
</table>

B. Fluid Resuscitation

Approximately a 25% diminution in blood volume is required to produce minimal clinical manifestations of shock. When shock is suspected, a fluid bolus, using warmed fluids whenever possible, of 20 mL/kg of crystalloid solution is an appropriate initial bolus. This represents 25% of the normal blood volume of a child (20 mL/kg divided by 80 mL/kg = 25%).

The injured child should be monitored carefully with respect to the adequacy of organ perfusion and response to the initial fluid challenge. Return of hemodynamic stability is indicated by:

1. Slowing of the heart rate (< 130 beats/minute).
2. Increased pulse pressure (> 20 mm Hg).
3. Decrease in skin mottling.
4. Increased warmth of extremities.
5. Clearing of sensorium.
6. Urinary output of 1 mL/kg/hour.
7. Increased systolic blood pressure (> 80 mm Hg).

Failure to improve hemodynamic abnormalities following the first bolus of resuscitation fluid mandates prompt involvement of a surgeon, raises the suspicion for continuing hemorrhage, and prompts the need for the administration of a second 20-mL/kg bolus of crystalloid fluid. Serious consideration should be given to the prompt infusion of 10 mL/kg of type-specific blood or O-negative packed red blood cells (P-RBCs) in this situation.

The resuscitation flow diagram is useful aid in the initial management of the injured child. (See Table 3, Resuscitation Flow Diagram for the Stable and Unstable Pediatric Patient.)
Table 3. Resuscitation Flow Diagram for the Stable and Unstable Pediatric Patient

20 mL/kg Ringer's Lactate as Bolus (May Repeat 1 Time) --> **Surgical Consultation:**

1. Hemodynamically Stable --> Further Evaluation:
   a. Observe
   b. Operation.

2. Hemodynamically Unstable --> 10 mL/kg P-RBCs:
   a. Stable --> Further Evaluation --> Operation
   b. Unstable --> Operation.

**C. Blood Replacement**

The child in severe hypovolemic shock who does not respond to an initial crystalloid bolus must have restoration of the circulating red blood cell mass to ensure adequate tissue oxygen delivery. Rapid transfusion of warmed, red blood cells should be considered as soon as adequate venous access has been established in the hypovolemic child. Children who have received the initial two boluses of 20 mL/kg of Ringer's lactate and have not responded clearly require immediate blood transfusion as well as ongoing crystalloid infusion. Further, children who respond initially, but whose conditions later deteriorate also are candidates for prompt infusion of red blood cells. Until type-specific blood is available, warmed type O, Rh-negative packed red blood cells (10 mL/kg) is appropriate. **Remember, evaluation by a surgeon is essential.**

**D. Venous Access**

Severe hypovolemic shock usually occurs as the result of disruption of intrathoracic or intra-abdominal organ systems. Venous access should preferably be established by a percutaneous route. The common femoral veins should be avoided in infants and children whenever possible because of the high incidence of venous thrombosis and the possibility of ischemic limb loss. If percutaneous venous access is unsuccessful after two attempts, consideration should be given to intraosseous infusion in children younger than six years of age or direct venous cutdown in children six years of age or older. Venous cutdown may be considered at these sites:

1. Greater saphenous at the ankle.
2. Median cephalic vein at the elbow.
3. Main cephalic vein higher in the upper arm.
4. External jugular, which also may be cannulated percutaneously.

Intravenous access in the hypovolemic child younger than six years of age is a perplexing and challenging problem, even in the most experienced hands. **Intraosseous infusion**, cannulating the marrow cavity of a long bone in an **uninjured** extremity, is an emergent-access procedure for the critically ill or injured child. The intraosseous route is safe,
efficacious, and requires less time than venous cutdown. However, intraosseous infusion should be discontinued when suitable peripheral venous access has been established.

Indications for intraosseous infusion are limited to children six years of age or younger, for whom venous access is impossible due to circulatory collapse or for whom percutaneous peripheral venous cannulation has failed on two attempts. Complications of this procedure include cellulitis and rarely, osteomyelitis. The preferred site for intraosseous cannulation is the proximal tibia, below the level of the tibial tuberosity. If the tibia is fractured, the needle may be inserted into the distal femur. Intraosseous cannulation should not be performed distal to a fracture site. (See Figure 1, Site for Intraosseous Infusion.)

Using a #16- or #18-gauge, one-half inch long, bone marrow aspiration/transfusion needle, entry is directed distally in the tibia and superiorly in the femur, with the bevel directed up to avoid the joint space and the physis. Aspiration of bone marrow contents identifies adequate needle position. Needle position also can be verified by the lack of resistance to infusion without soft-tissue extravasation. Crystalloids, blood products, and drugs may be administered via the intraosseous route. Circulation time from the marrow cavity to the heart is generally less than 20 seconds. Effective volume resuscitation can be accomplished by this method.

E. Thermoregulation

The high ratio of body surface area to body mass in children increases the facility with which heat exchange occurs with the environment, and directly affects the child's ability to regulate core temperature. Thin skin and the lack of substantial subcutaneous tissue contribute to increased evaporative heat loss and caloric expenditure. Hypothermia may render the injured child refractory to treatment, prolong coagulation times, and adversely affect central nervous system function. While the child is exposed during the initial survey and resuscitation phase, overhead heat lamps or heaters or thermal blankets may be necessary to maintain body temperature. Warming the room as well as intravenous fluids and blood products is necessary to preserve body heat.

IV. Chest Trauma

Blunt thoracic trauma is common in children and often requires immediate intervention to establish adequate ventilation. The child's chest wall is very compliant, allowing for the transfer of energy to the intrathoracic soft tissues, frequently without any evidence of injury to the external chest wall itself. The specific abnormalities caused by thoracic trauma in the child are identical to those encountered in the adult, and usually can be treated without thoracotomy. The management approach is the same.

Mobility of mediastinal structures makes the child more sensitive to tension pneumothorax and flail segments. The pliable chest wall increases the frequency of pulmonary contusions and direct intrapulmonary hemorrhage, usually without overlying rib fractures. However, the identification of rib fractures in young children implies massive energy transfer, severe associated organ system injury, and a poorer prognosis. Therefore, children sustaining multiple rib fractures should be transported to a facility capable of providing optimal management.
Children sustain bronchial injuries and diaphragmatic ruptures more frequently than adults due to blunt crushing forces. Injury to the great vessels is infrequent compared with that in the adult. Significant injuries rarely occur alone and are frequently a component of major multisystem injury.

**Penetrating thoracic injury** is rare in the preadolescent child; however, it represents an increasing cause of injury after 10 years of age. Penetrating trauma to the chest is managed in the same manner as in the adult.

V. Abdominal Trauma

Most pediatric abdominal injuries occur as the result of blunt trauma, primarily in the situations involving motor vehicles and falls.

Penetrating abdominal injuries, which increase during adolescence (both intentional and unintentional), dictate prompt involvement by the surgeon. As in the adult, the hypotensive child who has sustained penetrating abdominal trauma should be assumed to have major intra-abdominal injury and require operative resuscitation.

A. Assessment

The conscious infant and young child are generally frightened by the events preceding admission to the emergency department, and this may influence the examination of the abdomen. While talking quietly and calmly to the child, ask questions about the presence of abdominal pain, and gently assess the tone of the abdominal musculature. Deep painful palpation of the abdomen should be avoided at the onset of the examination to prevent voluntary guarding that may confuse the abdominal findings. Almost all infants and young children who are stressed and crying will swallow a large amount of air. Decompression of the stomach by inserting a gastric tube, as in the adult, should be a part of the resuscitation phase. Orogastric intubation is preferred in infants. Tenseness of the abdominal wall often decreases as gastric distention is relieved. The abdomen then can be carefully and more reliably evaluated. Abdominal examination in the unconscious patient will not vary greatly with age. Decompression of the urinary bladder will facilitate abdominal evaluation.

B. Peritoneal Lavage

Although the interpretation of the results of peritoneal lavage is the same for the pediatric and the adult patient, the procedure is performed less often in children. Peritoneal lavage is a useful technique in the evaluation of the hemodynamically unstable child.

As in the adult, use a buffered Ringer's lactate solution in volumes of 10 mL/kg up to 1000 mL, with the solution running over a 10-minute period. The fluid should be warmed. It is important to remember that the child's abdominal wall is relatively thinner than in the adult. Sudden penetration of the abdominal cavity can produce iatrogenic injury to the abdominal contents, even using the open technique. Peritoneal lavage has utility in diagnosing injuries to intra-abdominal viscera only. Retroperitoneal organs cannot be evaluated reliably by this technique.
Because nonoperative management requires surgical supervision, diagnostic peritoneal lavage in a child should be performed only by the surgeon who will care for the patient.

C. Computed Tomography

Many surgeons use computed tomographic (CT) scanning in place of peritoneal lavage, and some use both. CT scans may be useful in the assessment of abdominal injuries in the hemodynamically stable child. If CT scanning is used to evaluate the abdomen of children sustaining blunt trauma, it must be immediately available, performed early, and not delay further treatment. The identification of intra-abdominal injuries by CT scan in otherwise stable pediatric patients may allow nonoperative management by surgeons when a positive lavage would have mandated celiotomy.

D. Nonoperative Management

Selective nonoperative management of children with blunt abdominal injuries is performed in many trauma centers. These children must be managed in a facility offering pediatric intensive care capabilities, and under the supervision of a qualified surgeon. Intensive care must include continuous nursing staff coverage, continuous monitoring of vital signs, and immediate availability of surgical personnel and operating room resources.

Nonoperative management of confirmed abdominal, visceral injuries requires the direction of a surgeon. The decision to manage the patient nonoperatively, to continue to manage the patient nonoperatively, or to operate is a surgical decision. Therefore, a surgeon’s involvement in the early management of the pediatric patient is absolutely necessary.

VI. Head Trauma

Information provided in Chapter 6, Head Trauma, also applies to pediatric patients. This section emphasizes additional points peculiar to children.

Most head injuries in the pediatric population are the result of motor vehicle crashes, bicycle accidents, and falls. Data from the National Pediatric Trauma Registry indicate that an understanding of the interaction between the central nervous system and extracranial injuries is imperative. Determinants of survival in this population are related more to associated injuries (lack of attention to the ABCs) than the head injury itself. As in the adult, hypotension is rarely, if ever, caused by head injury alone, and other explanations for this finding should be investigated aggressively.

A. Assessment

Children and adults may differ in their response to head trauma, which may influence the evaluation of the injured child. The principal differences include:

1. Although children generally recover from head injuries better than adults, children younger than three years old have worse outcomes from severe head trauma than older
children. Children are particularly susceptible to the effects of the secondary brain injury that may be produced by hypoxia, hypotension with reduced cerebral perfusion, seizures, or hyperthermia. Adequate restoration of an appropriate circulating blood volume is mandatory and hypoxia must be avoided.

2. Although an infrequent occurrence, infants may become hypotensive from blood loss into either the subgaleal or epidural space. Treatment is directed toward appropriate volume restoration as it is with blood loss from other body regions.

3. The young child with an open fontanelle and mobile cranial suture lines is more tolerant of an expanding intracranial mass lesion. Signs of an expanding mass may be hidden until rapid decompensation occurs. Therefore, an infant who is not in coma, but who has a bulging fontanelle or suture diastases should be treated as having a more severe injury. Early neurosurgical consultation is essential.

4. Vomiting is common after head injury in children and does not necessarily imply increased intracranial pressure. However, persistent vomiting or vomiting that becomes more frequent is of concern and demands CT of the head. Gastric decompression is essential, because of the risk of aspiration.

5. Seizures occurring shortly after head injury are more common in children and are usually self-limiting. Recurrent seizure activity requires investigation by CT scanning.

6. Children tend to have fewer focal mass lesions than adults, but elevated intracranial pressure due to cerebral edema is more common. In children, a lucid interval may be prolonged, and the onset of neurologic deterioration may be delayed for this reason. Although rapid restoration of appropriate circulating blood volume is necessary, overhydration, especially with hypotonic fluids, should be avoided. Emergency CT is vital to identify those children who require emergency surgery.

7. The Glasgow Coma Scale (GCS) is useful when applied to the pediatric age group. However, the verbal score must be modified for children younger than four years of age. (See Table 4, Pediatric Verbal Score.)
<table>
<thead>
<tr>
<th>Verbal Response</th>
<th>V-Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appropriate words or social smile, fixes and follows</td>
<td>5</td>
</tr>
<tr>
<td>Cries, but consolable</td>
<td>4</td>
</tr>
<tr>
<td>Persistently irritable</td>
<td>3</td>
</tr>
<tr>
<td>Restless, agitated</td>
<td>2</td>
</tr>
<tr>
<td>None</td>
<td>1</td>
</tr>
</tbody>
</table>

8. Because of the frequency for developing increased intracranial pressure in children, intracranial pressure monitoring should be considered **early** in the course of resuscitation for children with:

a. A GCS Score of eight or less, or motor scores of one or two.

b. Multiple injuries who require major volume resuscitation, immediate life-saving thoracic or abdominal surgery, or for whom stabilization and assessment will be prolonged.

9. Medication dosages must be adjusted as dictated by the child's size, and in consultation with a neurosurgeon. Frequently used drugs in children with head injuries include:

a. Phenobarbital - 2 to 3 mg/kg.
b. Diazepam - 0.25 mg/kg, slow IV bolus.
c. Phenytoin - 15 to 20 mg/kg, administered at 0.5 to 1.5 mL/kg/minute as a loading dose, then 4 to 7 mg/kg/day for maintenance.
d. Mannitol - 0.5 to 1.0 g/kg.

B. Management

Successful management of diffuse axonal injury in children involves:

1. Rapid, early assessment and management of the airway, respiration, and circulatory system.


3. Appropriate sequential assessment and management of the brain injury with attention directed toward the prevention of secondary brain injury, ie, hypoxia and underperfusion. Early endotracheal intubation with adequate oxygenation and ventilation are indicated to avoid progressive central nervous system damage. Attempts to orally intubate the trachea in the uncooperative, head-injured child may be difficult and actually increase intracranial pressure. Based on the intubation skills of the physician, iatrogenic paralysis to facilitate intubation potentially risks the life of the patient. Therefore, this modality should be employed only by the physician who has considered the risk and benefits of intubating the child and who is confident of his intubation abilities.

4. Continuous reassessment of all parameters.
VII. Spinal Cord Injury

Information provided in Chapter 7, Spine and Spinal Cord Trauma, also applies to pediatric patients. This chapter emphasizes the peculiarities of pediatric spinal injury.

Spinal cord injury in children is fortunately rare. Only 5% of all spinal cord injuries occur in the pediatric age group. For children younger than 10 years of age, motor vehicle crashes most commonly produce these injuries. For children aged 10 to 14 years, motor vehicles and sporting activities account for an equal number of spinal injuries.

A. Anatomic Differences

1. Interspinous ligaments and joint capsules are more flexible.

2. The uncinate articulations are poorly developed and incomplete.

3. Vertebral bodies are wedged anteriorly and tend to slide forward with flexion.

4. The facet joints are flat.

5. The child has a relatively large head compared with the adult, and more angular momentum can be generated during flexion or extension, resulting in greater energy transfer.

B. Roentgenographic Considerations

Pseudosubluxation - About 40% of children younger than seven years of age show anterior displacement of C-2 on C-3. About 20% of children up to 16 years of age exhibit this phenomenon. Although this radiographic finding is seen less commonly at C-3 to C-4, more than 3 mm of movement can be seen when these joints are studied by flexion and extension maneuvers.

Increased distance between the dens and the anterior arch of C-1 occurs in about 20% of young children. Gaps exceeding the upper limit of normal for the adult population are frequently seen.

Skeletal growth centers can resemble fractures. Basilar odontoid synchondrosis appears as a radiolucent area at the base of the dens, especially in children younger than five years of age. Apical odontoid epiphyses appear as separations on the odontoid roentgenogram and are usually seen between the ages of five and eleven years. The growth center of the spinous process may resemble fractures of the tip of the spinous process.

Children may sustain spinal cord injury without radiographic abnormality more commonly than adults. A normal spine series can be found in up to two thirds of children suffering spinal cord injury. Therefore, if spinal cord injury is suspected, based on history or results of the neurologic examination, normal spine roentgenograms do not exclude significant spinal cord injury. When in doubt about the integrity of the cervical spine, assume that an unstable injury exists, maintain immobilization of the child’s head and neck, and obtain appropriate consultation.
VIII. Extremity Trauma

The initial priorities in the management of skeletal trauma in the child are similar to those for the adult, with the additional concerns about potential injury to the growth plate.

A. History

History is of vital importance. In the younger child, roentgenographic diagnosis of fractures and dislocations is difficult because of the lack of mineralization around the epiphysis and the presence of a physis (growth plate). Information about the magnitude mechanism and time of the injury facilitates better correlation of the physical findings and roentgenograms. Radiographic evidence of fractures of differing ages should alert the physician to possible child abuse.

B. Blood Loss

Blood loss associated with long bone and pelvic fractures is proportionately greater in the child than in the adult. Even a small child can lose up to one unit of blood into the muscle mass or the thigh, and hemodynamic instability may develop as the result of a fractured femur.

C. Physeal (Growth Plate) Fractures

Bones lengthen as new bone is laid down by the physis near the articular surfaces. Injuries to, or adjacent to, this area before the physis has closed can potentially retard the normal growth or alter the development of the bone in an abnormal way. Crush injuries, which are often difficult to recognize radiographically, have the worst prognosis.

D. Fractures Unique to the Immature Skeleton

The immature, pliable nature of bones in children may lead to a so-called "green-stick" fracture. Such fractures are incomplete, with angulation maintained by cortical splinters on the concave surface. The torus or "buckle" fracture, seen in small children, involves angulation due to cortical impaction with a radiolucent fracture line. Supracondylar fractures at the elbow or knee have a high propensity for vascular injury as well as injury to the growth plate.

E. Principles of Immobilization

Simple splinting of fractured extremities in children is usually sufficient until definitive orthopedic evaluation can be performed. Injured extremities with evidence of vascular compromise require emergent evaluation to prevent the adverse sequelae of ischemia. A single attempt at reduction of the fracture to restore blood flow is appropriate followed by simple splinting or traction splinting of the femur.
IX. The Battered, Abused Child

The battered, abused child syndrome refers to any child who sustains a nonaccidental injury as the result of acts by parents, guardians, or acquaintances. Children who die within the first year of life from injury usually do so as the result of child abuse. Therefore, a history and careful evaluation of the child suspected of being abused is critically important to prevent eventual death, especially in children who are younger than one year of age. A physician should suspect abuse if:

1. A discrepancy exists between the history and the degree of physical injury.
2. A prolonged interval has passed between the time of the injury and the seeking of medical advice.
3. The history includes repeated trauma, treated in different emergency departments.
4. Parents respond inappropriately or do not comply with medical advice, eg, leaving a child in the emergency facility.
5. The history of injury changes or differs between parents or guardians.

These findings, on careful physical examination, should suggest child abuse and indicate more intensive investigation:

1. Multiple subdural hematomas, especially without a fresh skull fracture.
2. Retinal hemorrhage.
3. Perioral injuries.
4. Ruptured internal viscera without antecedent major blunt trauma.
5. Trauma in the genital or perianal areas.
6. Evidence of frequent injuries typified by old scars or healed fractures on roentgenograms.
7. Fractures of long bones in children younger than three years of age.
8. Bizarre injuries such as bites, cigarette burns, or rope marks.
9. Sharply demarcated second- and third-degree burns in unusual areas.

In every state, physicians are bound by law to report incidences of child abuse to governmental authorities, even cases where abuse is only suspected. Abused children are at increased risk for fatal injuries, and no one is served by failing to report. The system protects physicians from legal liability for identifying confirmed or even suspicious cases of abuse. Although the reporting procedures may vary from state to state, it is most commonly handled
through local social service agencies or the state's Health and Human Services Department.

X. Epidemiology of Injury in Children and Strategies for Injury Control

Considering the devastating impact that childhood injuries may have on the child, and his/her family, the physicians involved in the care of children have an obligation to be engaged in efforts directed toward injury prevention. Blunt injuries predominate in the pediatric population, but penetrating injuries appear to be on the increase, particularly in adolescents and teenagers. If physicians can convince the lay public that "accidents" are not random events beyond the control of society, then much can be done to prevent injuries. Programs for injury prevention should begin in the home. Parents should be counseled on appropriate supervision during play time activities, poison prevention, fall precautions, and should be encouraged to take classes in cardiopulmonary resuscitation. Bicycle safety programs should be introduced into the school curricula of all elementary schools. The use of the bicycle helmets has been shown to effectively reduce the number and seriousness of head injuries, and these programs should be introduced and encouraged for all cyclists. Given the fact that even minor head injuries may have profound influences on the physical, cognitive, emotional, and social aspects of development, all efforts in the area of head injury prevention are certainly justifiable.

Identification of children at risk for injury is somewhat more problematic. Epidemiologists have identified preliminary risk factors that are worthy of consideration, and involve environmental and social characteristics that can be recognized. Signs of stress and discord within family units have been statistically associated with increased risk of injury. Other related factors to the potential for injury, though perhaps not casually, include a chronic medical condition, weight in the lowest 25th percentile, birth order third or later, and maternal education level greater than high school.

The issues concerning whether children who sustain one injury are at higher risk for subsequent injuries and the concept of the "accident-prone" child are controversial. However, studies have produced evidence that suggests that a significantly greater proportion of school-aged children who sustained more than one injury did so at a rate greater than could have been accounted for by chance alone. A group of recurrently injured children, composing only one percent of the injured pediatric population, sustained nearly one fifth (20%) of all the injuries identified. Further, injuries occurred more frequently in school systems with "open" classrooms, junior high schools, extended hours, magnet curricula, and those with active athletic programs. The association of these factors with childhood trauma is an important marker for the development of injury awareness programs in the community. Children at potentially greater risk for injury might be identified.

The problem of social violence is increasing throughout the United States and the pediatric age group is not immune. The association of pediatric injury with the increasing use of drugs and other substances of abuse is suggestive, but it lacks confirmatory evidence. No doubt, the availability and access to hand guns and other weapons contribute to the problem. While preventive measures in scenarios involving violence may be difficult to identify prospectively, school-sponsored drug and alcohol awareness programs, gun control, gun safety, and even programs designed to teach appropriate measures for dealing with anger and conflict would be beneficial. Physicians should be able to identify parents who lack sufficient
parenting skills or reside in pathologic environmental situations. Referrals to appropriate social agencies who could render assistance would be prudent in these situations. It may be unfortunate that often the families in need of such services are identified after the fact, but an opportunity does exist for the physician to intervene when circumstances suggest correctable social, psychologic, or environmental predisposing factors.

Legislative activity to mandate safety (seat belt laws, child restraint legislation, requirements for helmets for cyclists, gun control, etc) is laudable. However, successful preventive programs must begin at the "grass roots" level. Physicians are in a unique position not only to identify the problem, but also to serve as role models and community leaders in this area. Despite the fact that all the answers to the problems of injury prevention do not exist, the medical community cannot afford to waste any opportunities considering the enormity of the impact of injuries in children.

IX. Summary

The recognition and management of pediatric injuries require the same astute skills as for adults. However, the unwary physician can make serious errors unless he is fully cognizant of the unique features of the pediatric trauma patient. These unique characteristics include airway anatomy and management, diagnosis of extremity fractures, and the recognition of the battered, abused child.

Early involvement of the surgeon or the pediatric surgeon is imperative in the management of the injured child. Nonoperative management of abdominal visceral injuries should be performed only by surgeons in facilities equipped to handle any contingencies in an expeditious manner. All physicians should be engaged in efforts to expand injury awareness and prevention in their communities.