

# **Aurora Health Care – South Region EMS**

## **2010 4th Quarter CE Packet**

### **PEDIATRIC TRAUMA**

Trauma is the primary cause of mortality and morbidity in the pediatric population. Although great efforts have been made to educate the public on many safety issues, unintentional injury and death rates in children remain high. Pediatric trauma should be considered a preventable disease.

While the number of motor vehicle related injuries continues to fall, the overall incidence of related pediatric trauma remains fairly stable. According to the Centers for Disease Control and Prevention (CDC), motor vehicle accidents (MVAs) are the leading cause of death among children in the U.S.

Mechanisms of injury vary by age group. Drowning and water injuries are the second leading cause of death for children 1 to 14 years of age, while suicide ranks third among children 10 to 14 years of age. Violence, maltreatment, poisonings, and unintentional injuries are also common causes of trauma in the pediatric population. The economic burden of injuries in children and adolescents is considerable and further exacerbated when factoring in the lifetime costs involved.

In caring for the injured child, it is imperative that the healthcare provider consider the unique anatomic and physiologic parameters of children. These factors predispose the child to unique patterns of injury as well as unique resuscitative requirements.

#### **BIOMECHANICS OF PEDIATRIC TRAUMA**

Most traumatic deaths occur during the first hour after injury. Interventions during this “golden hour” are aimed at preservation of blood volume and reduction of the effects of severe traumatic brain injury (TBI). The majority of these injuries may not be survivable; however, all efforts should be instituted to support the life of the child during this time.

Once stabilized, the risk of death remains high during the next 23 hours. The child who has sustained trauma to major body organs and has ongoing hemorrhage may not survive this period. Additionally, significant head injury may cause massive swelling and subsequent herniation and death. It is during this time period that aggressive resuscitation efforts may positively impact patient outcomes.

Optimistically, the child will survive this first 24 hours; however, astute assessment and interventions continue to be required to reduce the effects of trauma, including multiple organ failure and post-traumatic respiratory distress syndrome. The risk of death and disability remains high during the first two weeks after injury. Although the child may survive this two week period, there are patterns of injury in which children sustain delayed onset of complications (greater than two weeks post injury) that carry a high risk of death. There are a number of factors that impact the pattern of injuries. Age, sex, behavior, and locale all influence the types of

injuries sustained. Children with the statistically highest risk of sustaining injury are school-aged boys. The injuries sustained at this age group will differ from those occurring during infancy or adolescence.

Infants (1 month to 1 year of age) are at risk for sustaining injury in the home environment. Falls, choking, and strangulation are leading causes of injury and death. Falls can occur from furniture, stairs, or while in walkers. Studies have noted the possibility of trauma associated with child carriers (such as portable car seats) when a child is left unattended and inadvertently tips the carrier. Children at this age may be unrestrained in a MVA and suffer significant multisystem injury. Child abuse is also prevalent at this age and is considered a form of trauma.

Toddlers (1 to 3 years of age) and preschoolers (3 to 6 years of age) sustain motor vehicle trauma, both as passengers and as pedestrians. Many bicycle deaths in this age group occur when a small child is struck by a car or truck because their small stature prevents them from being seen by rearview mirrors. Some vehicles now have rearview cameras to help prevent this type of accident. The inquisitive nature of children in this age group also increases the risk of injury. Falls, poisonings, burns, and drowning occur when children are unattended and encounter danger that they cannot defend themselves against nor comprehend. The toddler and preschooler can also be victims of abuse and homicide.

The largest risk of injury occurs during the school age years (7 to 12 years of age). These children are developing a sense of independence and freedom, which predisposes them to new risks. Many school age children are injured while riding in a motor vehicle. A unique injury in children is known as “lap belt complex,” whereby the child sustains injury secondary to the lap belt restraint.

School-age children are the most likely age group to sustain injury while riding a bicycle. Although bicycle helmet laws exist in many states, the compliance with such laws remains low. It is important to note that the use of a bicycle helmet can reduce the risk of brain injury by as much as 88%.

Other types of injuries in children 7 to 12 years of age include falls, poisonings, and drowning. The incidence of personal violence increases, and the number of suicides in this age group is increasing annually. The incidence of school ground trauma has also become more prevalent.

Many teenagers (13 to 19 years of age) are injured in automobiles. As these children begin to drive, the risk of both driver and occupant injuries becomes more common. Studies have shown the incidence of injury increases with the number of peers in an automobile, thus reigniting the debate regarding restricting driving privileges of young, newly licensed drivers.

Many socioeconomic and cultural influences impact the type and incidence of trauma. Urban children have a higher incidence of violence; the presence of youth gangs, alcohol use, and drug use is highest in this environment. Patterns of behavior and injury are also impacted by the race of the child; young African American men who are 15 to 19 years of age have the highest proportion of homicide deaths, frequently precipitated by firearms. The suicide rate in teenage individuals has increased during the last three decades. Five thousand adolescents take their own

lives annually. White teenage boys have the highest rate for suicide deaths, and for each fatality there are 31 nonfatal attempts.

Alcohol and drug use increases during this age, and the impact of impaired behavior will influence injury and death rates. Younger teens may experiment with inhalants; “huffing” or sniffing volatile agents will increase the risk of sudden sniffing death (SSD). It is estimated that there are more than 1400 agents available over the counter that can be legally purchased by young teens as a method of getting high.

An emerging area of research in trauma epidemiology is the impact of activities on traumatic injury and death. Head injuries and sudden cardiac death are just two of the areas of study; sporting activities can also cause a multitude of orthopedic and musculoskeletal injuries. Football, soccer, baseball, and skateboarding are just a few of the sports that have been recognized as injury producing activities.

Traumatic injuries can present as either penetrating or blunt injuries. Although the incidence of penetrating injuries in pediatric patients is less than in adult trauma victims, the number of gun and knife injuries is increasing. While penetrating trauma can be more easily recognized and diagnosed, blunt injuries can be equally life threatening.

Blunt injuries present the challenge of recognition of injury and appropriate diagnosis. Missed injuries secondary to blunt trauma pose a risk, especially in the pediatric patient. Many missed injuries are thought to be related to the level of consciousness of the child; however, a study showed that the inability to communicate was not associated with an increased incidence of missed injury. This same study noted that the number of missed injuries was significant, as high as 20%. It is imperative that healthcare providers caring for pediatric victims be aware of this risk.

### **SPECIFIC MECHANISMS OF INJURY**

When the report of a traumatized child is obtained, one of the first questions to be answered is, “How was the child injured?” Once the mechanisms of injury are identified, the diagnosis of the injuries is much easier.

Many children are injured in MVAs whether they are restrained or not. Unrestrained children often suffer numerous injuries when a MVA occurs. At the time of the crash, the unrestrained child becomes a projectile and is either thrown around the interior of the vehicle, impacting with the hard frame, or is ejected, suffering multiple injuries upon impact with the ground. The incidence of head injury increases by more than 300% when a passenger is unrestrained.

Children riding in cars equipped with airbags are known to be at increased risk of injury secondary to the impact of the airbags against their small body frames. It is recommended that all children younger than 12 years of age be placed in the back seat of an automobile equipped with front passenger side airbags. The first airbags were designed to protect a 70 kg man riding in the passenger seat. The airbag was discharged at a speed of more than 200 miles per hour and was aimed at the thorax. For a child sitting in this same seat, the direction of the airbag impact is at the head and neck of the child. Many children have died secondary to airbag injuries, primarily due to trauma of the head and neck. New generation “smart” airbags are being installed in new

model cars; these bag devices are able to detect the weight of the passenger and the speed of the impact and the bag can be released at a lower velocity. Regardless, the recommendation to reduce the risk of injury and death remains the placement of the child in a rear seat. It must be noted, however, that passengers in this rear compartment are also at risk for injury. New side impact airbags that are installed on the rear side windows have caused death and injury to children who have inadvertently fallen asleep against the door and are injured when the airbag is deployed, causing lateral disruption of their cervical spine. Seat belt restraint devices can also be the cause of an injury. Lap belt complex occurs when a restraining device is improperly utilized. In older vehicles equipped with a single lap belt, the child can sustain injury if the device is not fastened low and tight across the pelvis. Two types of injuries are noted. The first is lap belt complex, in which injury occurs to the liver and/or spleen when the belt is riding high on the child's abdomen and is suddenly retracted during a crash. Additionally, the bowel can rupture, causing spillage of bowel contents into the abdominal cavity. The second type of injury occurs when the lap belt is loosely applied around the abdomen of a small child. In a high speed crash, the child slips under the belt and catches his or her chin on the belt, causing a hangman-type fracture of the second cervical vertebrae. This type of injury is known as submarining, as the child slips under the belt.

Car seats for infants and small children have significantly reduced death rates of children in automobile crashes. Since their use has been mandated, the number of fatalities has dropped 71%. However, statistics demonstrate that 80% of car seats are incorrectly installed or inadequately secured. The American Academy of Pediatrics Committee on Injury and Poison Prevention issued recommendations concerning safety seat selection and use. They strongly suggest that small children be placed in rear seats and facing backward until they are at least 1 year of age and weigh more than 20 pounds.

An additional type of vehicular trauma in pediatric patients occurs in school age children riding on school buses. Statistics show that there are 9 deaths and 8500 injuries related to school buses each year in school age children. An additional 26 children die annually as pedestrians when either leaving or boarding the bus. These children are frequently the victims of drivers who try to illegally pass a school bus when the red lights are flashing.

During the teenage years, an additional type of injury that occurs as a result of an automobile occurs when a teen is "car surfing". Car surfing can take one of two forms. In the first instance, the child is riding either on the hood or the top of the passenger compartment in a surfing type stance. When the car accelerates or decelerates, the child is thrown to the ground, most often asphalt or other hard surface, and sustains major head trauma. If the child is thrown off the automobile, the driver may be unaware of this fall and continue to drive, possibly driving over the victim, causing a crush injury. The second activity occurs when either a bicyclist or skater holds either the door handles or the bumpers of the car, and is pulled by the car (this is known as bumper hitching). This child may also be run over when they inadvertently slip and fall under the wheels. In most instances, the victims (and drivers) do not recognize the inherent danger in these activities. The common remark after such trauma is, "I wasn't going very fast." Many victims of pediatric trauma do not comprehend the consequences of their activities until it is too late.

Each year in the United States, 430,000 children are injured while riding bicycles and 300 die. Bicycles are the leading cause of mild traumatic brain injury (MTBI) in children. Small children

on three-wheeled bikes may not be seen in a rearview mirror and may be run over by a car or truck, commonly in their own driveway. Older school-age children are also frequently injured on bikes, and the use of helmets should be stressed in this population. It is important that the helmet fits correctly so that it is not dislodged during a fall. Many helmets are too loose, which negates the protection they can afford. A chinstrap should be tight enough to allow only a finger to be slipped between the strap and the chin.

Bicyclists sustain a variety of injuries, with head injuries having the greatest risk of death and disability. Many bicyclists are hit by moving vehicles and can be thrown under the tires of the car or truck. The child can sustain multiple orthopedic injuries as well as cutaneous injury secondary to skidding across an uneven, rocky surface.

Another form of recreational activity that may present a risk is the use of small wheel skates, such as inline skates, roller skates, scooters, and skateboards. The majority of injuries sustained during this activity include trauma to the upper extremities, with the most common major injuries occurring in the forearm or hand. The use of protective gear, including helmets, wrist guards, knee pads, and elbow pads, helps reduce the number and severity of injuries.

All children who participate in organized sports are at risk for certain types of injuries. In the United States, football accounts for 60% of all MTBIs sustained while participating in a sport. While football is the leading cause of this type of injury in men, soccer is the leading cause for women. After bicycling, football, basketball, playground recreation, and soccer are the leading causes of TBI in children 5 to 18 years of age. The American Academy of Neurology has set guidelines for player evaluation and return to play; unfortunately, these guidelines are overlooked in some cases, and a player is returned to play sooner than would be prudent. Team physicians should not yield to a coach's urging to return a player to the field.

Throughout the history of football, several changes have helped to minimize direct and indirect injury and death, including the prohibition of head-first tackling, helmet requirements, improved coaching techniques, and advancements in medical care. In spite of these improvements, injuries are still common. Players tend to incur more injuries during competition than during practice, and subdural hematomas are the most common injuries in football. Studies show that considerable cognitive decline occurs in players who have incurred subdural hematomas and other types of head trauma. Some head injuries can cause permanent disability. To further aggravate the problem, one study showed that more than one third of players studied "were playing with residual neurologic symptoms from the prior head injury".

Soccer is the most popular sport in the world, and the number of children participating in organized soccer leagues is greatly increasing, especially in the United States. More than 6 million American children play organized soccer. Many parents proclaim soccer to be a "safe" sport when compared to football and direct their children to this arena. Interestingly, the injury rate associated with soccer is twice as high in girls as in boys. In soccer, the cranium has more contact with the ball than in other sports. The concern that "heading," using the head to pass the ball, impairs cognitive function remains controversial. Several leading organizations have conducted research in this area, but no recommendations have been made.

One of the fastest growing winter recreational activities, which is especially popular among teens, is snowboarding. Injuries sustained from snowboarding differ from ski injuries. Twisting knee injuries, as seen in skiers, are rare as both feet are fixed together on the board. However, snowboarders suffer an increased number of upper extremity injuries. Injuries to the wrist are the most common trauma sustained while snowboarding.

Personal watercraft related injuries are more prevalent than injuries from all other water sports. Common injuries associated with these activities include trauma to the head, face, chest, spine, and abdomen.

Extreme forms of trauma are being seen more frequently in the pediatric population, as more teenagers than ever before are trying extreme activities such as bungee jumping. With new forms of recreation come new mechanisms of injury, and it is the healthcare professional's responsibility to keep up with these advances in injury recognition so that the next time a pediatric patient sustains trauma, the potential and real injuries can be recognized without delay.

### **PRIMARY SURVEY**

Immediate measures in trauma resuscitation for a patient of any age include management of the airway, breathing, and circulation (ABC) while simultaneously determining if the child has sustained any life threatening injuries. In the child, these steps take on even more importance, as the loss of the airway in a child can be rapid and result in devastating consequences. As the ABCs are stabilized, the primary survey includes assessment of the level of disability and requires a complete examination of the child for rapid identification of any underlying injuries. The primary survey should take no longer than 5 to 10 minutes for assessment and stabilization.

Airway management of the child is critical and must be obtained as rapidly as possible. The limited size of the pediatric airway increases the risk of rapid deterioration and subsequent difficulties in managing the airway. Although the occurrence of spinal cord injury is rare in young children, all pediatric trauma patients should be managed as if a spinal cord injury exists. This requires utilizing the jaw thrust maneuver to open the airway while maintaining alignment of the cervical spine. Once positioned, the airway should be examined for debris, such as loose teeth, blood, or saliva that can be mechanically removed. Injuries that may complicate airway management include those of the face, including facial fractures, mandibular fractures, and fractures of the maxilla. These injuries produce rapid swelling and the visual loss of anatomic structures.

After securing the airway, ventilatory efforts must be ensured and supported as necessary. The child's rapid respiratory rate requires the care provider to ventilate the child at a faster rate than would be utilized in the adult trauma patient. Choosing the appropriate size resuscitation bag (ambu bag) is critical to prevent over distention of fragile lung tissue. Tidal volumes in children are calculated on a weight basis: 5–10 cc per kilogram of body weight.

Supplemental oxygen should be utilized, as children have high oxygen demands and become hypoxic quite quickly. As soon as possible a pulse oximeter probe should be applied, and monitoring of the child's oxygen saturation should be instituted. Oxygen desaturation can be a sign of developing respiratory failure and is helpful in providing real time information regarding the patient's oxygenation status.

Circulatory support is the next step in the resuscitation process. Assessment of circulation in children involves assessment of the pulse rate, pulse strength, skin color, and capillary refill time. Assessment of blood pressure should be obtained; however, it is important to remember that children have an exceptional ability to maintain normal vital signs in the face of significant volume loss.

Control of ongoing hemorrhage must be the first step in circulatory support; subsequently, vascular access should be initiated. Obtaining vascular access is often difficult in the small child; venous cannulation should be attempted as soon as possible for improved success. The longer the cannulation is delayed, the greater the incidence of failure. Optimally, the child who is hemorrhaging should have two large bore lines placed, preferably in the antecubital fossa. If intravenous (IV) line placement is unsuccessful in small children younger than 4 years of age, intraosseous (IO) line placement should be obtained. Intraosseous lines can provide rapid access to the central circulation; large amounts of fluid and/or blood products can be administered, and all medications are safe to administer via this route.

## **SECONDARY SURVEY**

The secondary survey is a systematic head-to-toe assessment of the traumatic injuries sustained. Ecchymosis and other signs of underlying injury should be identified. Although not all traumatic injuries are clear cut and initially obvious, mechanisms of injury help direct the EMT in identifying potential injuries. Beginning at the head of the child, the scalp is palpated and assessed for lacerations and irregularities in the shape of the skull. In infants, the fontanel's should be examined for fullness and/or widening. The facial structures should be assessed for integrity or instability. The eyes should be examined for foreign bodies or other abnormalities. Drainage of cerebral spinal fluid (CSF) from the nose and ears should be identified. The mouth should be inspected for lost or loose teeth, bleeding, and secretions.

Neurologic assessment should include the patient's level of consciousness, Glasgow Coma Scale (GCS) score, and pupillary response. Intact brain stem reflexes indicate an intact neurological pathway. Motor and sensory function should be evaluated.

## **PEDIATRIC GLASGOW COMA SCALE**

### **Score**

### **Responses by Age**

#### **Eyes Opening**

	<b>Patient &gt;1 year of age</b>	<b>Patient &lt;1 year of age</b>
4	Spontaneously	Spontaneously
3	To verbal command	To shout
2	To pain	To pain
1	No response	No response

## Motor Response

	Patient >1 year of age	Patient <1 year of age
6	Obeys	Spontaneous
5	Localizes pain	Localizes pain
4	Flexion-withdrawal	Flexion-withdrawal
3	Flexion abnormal (e.g., decorticate rigidity)	Flexion abnormal (e.g., decorticate rigidity)
2	To pain	To pain
1	No response	No response

## Verbal Response

	Patient >5 years of age	Patient 2 to 5 years of age	Patient ≤23 months of age
5	Oriented and converses	Appropriate words or phrases	Smiles or coos appropriately
4	Disoriented and converses	Inappropriate words	Cries and consolable
3	Inappropriate words	Persistent cries and/or screams	Persistent inappropriate crying and/or screaming
2	Incomprehensible sounds	Grunts	Grunts or is agitated or restless
1	No response	No response	No response

## TRAUMA TO THE HEAD AND FACE

The most life threatening of all traumatic injuries in the pediatric population are those that occur to the head and face. Traumatic Brain Injury (TBI) is a major cause of death and disability. According to the CDC, the pediatric population, particularly children 0 to 4 years of age and 15 to 19 years of age, is at greatest risk for TBI .

Trauma to the head and face can cause injury to the scalp, skull, facial structures, and brain, although survival and outcomes are directly determined by the extent of injury to the brain. The majority of traumatic injuries affecting the head and face are a direct result of MVAs and falls. Motor vehicle versus pedestrian injuries are common in school age children while child abuse is a major cause of brain injury in children younger than 1 year of age. Additional mechanisms of injury include bicycle injuries and assaults. Boys have a higher incidence of head trauma than girls.

## **HEAD TRAUMA**

Traumatic injuries to the head may impact the skull, the neural tissue, and/or the cerebral vasculature. An extensive amount of research and study is directed at either mild (minor) or major, extensive brain injury. This section will focus first on the types of injuries and the unique patterns of injuries seen in children, followed by an in-depth discussion of the treatment and outcomes following both minor and major brain injury.

When the head is injured, it is important to remember that two types of injury are possible: primary and secondary. Primary injury is that injury to the head and brain that occurs at the time of trauma. Secondary injuries occur as a result of the trauma; examples include cerebral edema, bony fragments, and delayed vascular injury. Trauma care of injuries to the head and brain is directed at preventing or controlling the development of secondary injury.

The most apparent head injury is a scalp laceration. Blunt force applied to the head will cause tissue disruption, leading to hemorrhage. In small children, uncontrolled hemorrhage may cause exsanguination attributable to the high density of the vascular bed in the scalp. In most patients, pressure dressings applied to the injury may slow or stop this loss of blood.

Seventy five percent of pediatric skull fractures are linear fractures, or simple cracks in the bone. Basilar fractures occur at the base of the skull and may be easily diagnosed by specific characteristic signs and symptoms. The child with a basilar skull fracture may exhibit CSF leakage from the nose (rhinorrhea) or ears (otorrhea), “raccoon eyes,” and hemotympanium. A delayed but diagnostic sign is ecchymosis over the mastoid region behind the ear (Battle’s sign), which may take up to 8 to 12 hours to appear.

A GCS score of 8 or less is an indicator of severe injury, and of these patients, 50% will die as a result of their injury. The most frequent pathologic finding after severe head injury is diffuse brain swelling and edema, and this is two to five times more common in children than adults.

Signs and symptoms suggestive of moderate-to-severe brain injury include a loss, or decreasing level, of consciousness, focal neurologic abnormalities, and coma. Management of neurotrauma in this population is based upon two mainstays of treatment: controlling hypotension and controlling hypoxemia. Initial resuscitative efforts should be directed at preventing these two complications, beginning in the field and progressing through the emergency department and into the critical care unit.

Hypotension in brain injured children can be caused by several reasons. Children can sustain acute blood loss from multiple traumatic injuries, and neurogenic hypotension can develop subsequent to the cerebral injury. Prehospital care providers must immediately control significant blood loss at the scene. Fluid resuscitation to prevent hypotension should be initiated early. Studies have shown that isolated hypotension in children can triple the mortality from pediatric brain injuries. Couple the hypotensive episode with hypoxemia, and the mortality rate can quadruple. Preventing hypoxemia means obtaining rapid control of the airway and supporting ventilation in the brain injured child.

## **FACIAL INJURIES**

Accompanying, and often complicating, cranial injuries can be injuries to the face. Injuries that

cause loss of facial integrity have the potential of preventing adequate airway management, leading to an increased risk of hypoxemia.

## **TRAUMA TO THE SPINE AND SPINAL CORD**

Although rare, pediatric spinal trauma is a devastating and life threatening injury. The types of spinal trauma sustained by children are age dependent and are, to some extent, due to the anatomic changes that occur with aging. Approximately 76% of injuries sustained involve the cervical portion of the neck. The majority of spinal injuries that occur in children occur in white male individuals who are involved in sports.

MVAs are by far the most common mechanism of injury to the spine in the pediatric population. In addition to MVAs, children sustain injuries in acts of violence, falls, and sports related activities. Compression and contusion injuries are more common than transection of the cord. The point of maximum mobility of the cervical region progresses downward with age. Maximal mobility is between C1 and C3 in the child younger than 8 years of age and between C3 and C5 in children 8 to 12 years of age. By 14 years of age, the adult pattern of mobility is seen, with maximum mobility at the C5 to C6 level. This mobility pattern sets the stage for the type of injury sustained. The younger child is more likely to have a higher level of injury than the older child.

## **RAPID NEUROLOGIC ASSESSMENT OF SPINAL CORD INJURIES**

<b>Assessment Parameter</b>	<b>Level of Function</b>
Elbow flexion	C5
Dorsiflexion of wrist	C6
Extension of the elbow	C7
Flexion of the middle finger phalanx of the middle finger	C8
Abduction of the little finger	T1
Flexion of the hip	L2
Extension of the knee	L3
Dorsiflexion of the ankle	L4
Dorsiflexion of the great toe	L5
Flexion of the ankle	S1
Bowel and bladder function	S2-4

## **CARDIOTHORACIC TRAUMA**

Trauma to the chest includes injuries to the pulmonary and cardiac systems. Thoracic injuries are

the second leading cause of death in children after trauma to the neurologic system. Diagnosis is often challenging, as external signs of trauma are often not present.

Children's chest walls are very pliable; therefore, rib fractures are less common than in adults. Pulmonary contusions account for the majority of traumatic injuries to the chest. Children with pulmonary contusions may or may not present initially with shortness of breath. The delay in symptom onset may be as long as 12 to 24 hours after injury. Bruising and tenderness over the chest wall may be the only presenting symptom and should cue the practitioner to the risk of pulmonary compromise. As the contusion develops, the child will experience increasing dyspnea, rales, hypoxemia, and possibly hemoptysis.

Management of developing pulmonary contusions depends upon the severity of symptoms. In severe cases, oxygen therapy and ventilatory support may be required, although this is quite rare in children.

A pneumothorax develops when air accumulates in the pleural space, leading to lung collapse. In children, the mechanism of injury is commonly blunt trauma to the chest, causing a burst type of injury of the lung tissue. The child will experience a sudden onset of chest pain with shortness of breath. Commonly, the pain associated with this injury will cause the child to take very shallow breaths; thus, auscultation of lung sounds is difficult. The area of the pneumothorax will have decreased or absent breath sounds and a hyperresonance to percussion.

A tension pneumothorax may develop after crush injury to the chest in which a pneumothorax develops and fails to seal, causing air to accumulate in the thoracic cavity and resultant compression of the lung tissue. As this pressure continues to build, the injured lung is deviated toward the uninjured side of the chest cavity. This causes a deviation of the trachea toward the unaffected side, severe respiratory distress, and cardiovascular compromise. The onset of symptoms is very rapid in small children due to the small size of their chest cavity. Immediate intervention requires efforts to release the pressure within the chest. The placement of a "flutter valve," a one way valve (also known as needle thoracostomy), into the 2nd or 3rd intercostal space midclavicular line will allow pressure release. Children will also benefit from high flow oxygen therapy to improve their oxygenation status.

A hemothorax is caused by an injury to the vascular system in the thoracic cavity that results in blood accumulation. Many of these injuries in children are caused by blunt chest trauma, although the most life threatening injuries follow penetrating trauma that causes direct injury to the thoracic vasculature. The lung has a low pressure vascular system that is capable of tamponading many sources of bleeding; therefore, small injuries may be self-limiting. In cases of massive hemothorax, the child will present with signs of hypovolemic shock, severe shortness of breath, and tachypnea. Blood replacement may be necessary to support the circulating volume. Monitoring blood loss in the child is critical, as a 20 cc/kg loss is equal to 20% to 25% of the child's blood volume.

Although rare, rib fractures and a flail chest can occur with significant force to the rib cage. A flail chest develops when two or more ribs are fractured in two places and the ribs become free floating. Fractures of the first two ribs may be associated with injury to either the brachial plexus

or the subclavian artery. Fractures of ribs 9 through 12 may be associated with injury to either the liver or the spleen.

The hallmark symptom of rib fracture is the early onset of dyspnea associated with significant pain. This leads to ineffective ventilation patterns and worsening respiratory failure. The key to improving oxygenation in the child is adequate pain control. If the pain can be controlled, the child will cooperate with the respiratory exercises that are necessary to keep the lungs expanded.

Trauma to the chest can also produce injury to the cardiovascular system. Pericardial tamponade and myocardial tissue damage can lead to cardiovascular collapse. Cardiac tamponade is most common after penetrating trauma to the chest; thus, it is more common in the adolescent than the younger child. Blood fills the pericardial sac, which is nondistensible, and compresses the heart. The severity of symptoms depends upon how rapidly the fluid accumulates; the faster the collection of blood, the more rapid the deterioration of the patient. The pericardial sac of the child is quite small, and a small amount of blood can lead to significant cardiac compromise. Children with tamponade will present with a weak, thready, rapid pulse. Signs of shock may develop as the cardiovascular system begins to fail. Beck's triad of symptoms (late signs of compromise) includes a decreased blood pressure with a narrow pulse pressure, distended neck veins, and distant heart sounds. These symptoms are documented in only 10% to 30% of cases, although these signs are considered "classic" signs of tamponade.

There has been increased interest in sudden cardiac death in children (known as *commotio cordis*), especially during athletic competition or exertion. More than 90% of these deaths occur in male patients. Some of these deaths occur when there is a sudden, blunt, modest blow to the mid-chest. Although this type of trauma occurs more frequently during sports, some occur during normal daily activities. The patient has no evidence of cardiac damage or disease in most cases, and death is secondary to ventricular fibrillation. It is suspected that the impact occurs during repolarization of the cardiac cycle, a time window of less than 1/100 of a second. On autopsy, those children who had no clinical signs of cardiac disease had evidence of hypertrophic cardiomyopathy or a congenital coronary artery anomaly. Only 25% of resuscitations are successful.

To reduce the incidence of sudden death, it has been recommended by the American Heart Association that participant screening be performed prior to participation in high risk sports. The screening done at present is inadequate and considered flawed in many instances. There are no specific training requirements to detect cardiovascular disease in children. Many athletes have a short evaluation performed by a physician with minimal training in evaluating for the risk factors associated with sudden death. Additional measures to reduce death include the development of safer equipment.

Other injuries occurring with trauma include diaphragmatic and tracheobronchial injuries. The diaphragm may tear with blunt force to the abdomen. This is caused by an increase in intraabdominal pressure that is transmitted to the diaphragm, causing it to tear. This tear most commonly develops in the left hemidiaphragm and can cause abdominal contents (most commonly the bowel and/or stomach) to enter the chest cavity. This produces signs of respiratory distress as the organs compress the lung.

Tracheobronchial injuries develop following a violent blunt force to the chest. Most injuries occur within 1 inch of the carina and are equally distributed between the right and left mainstem bronchus. Tears may be complete or incomplete. Small, incomplete tears may not be evident for up to 3 to 4 days after injury. The child is admitted with significant dyspnea and hemoptysis, and intubation is often required to support the child's respiratory effort. Tracheobronchial injuries should always be considered with a high index of suspicion when there is fracture of the upper five ribs and persistent pneumothorax with dyspnea. The overall mortality following these injuries is 20%, partially due to concomitant injury to the head, neck, spine, and chest. Large tears will require surgical repair while small tears are allowed to heal on their own.

When caring for the child with blunt thoracic trauma, it must be remembered that 12% of patients will have a concurrent cervical injury and must be treated with cervical spinal precautions. Although 85% of the injuries can be managed conservatively with ventilatory support and improvement in the oxygenation status of the child.

## **ABDOMINAL AND GENITOURINARY TRAUMA**

Abdominal and GU trauma is the leading cause of unrecognized fatal injury in children. Although the incidence of death from these injuries remains low, a missed injury can have a devastating outcome. The majority of children who die after sustaining abdominal trauma expire from an associated injury, most commonly head injury.

Children sustaining abdominal trauma demonstrate different injuries than those seen in adult trauma patients. The solid organs (spleen, liver, and kidneys) are proportionately larger and more prone to direct injury. Additionally, these organs are not well protected by fat pads, decreasing the protection afforded by fatty tissue. The organs are more frequently torn, especially from the pedicle. The adult's fat pads help to secure the organs in place. Without this support, the organs are suspended in the abdominal cavity and can sustain shearing injury with acceleration/deceleration forces. Abdominal trauma in children is also more difficult to assess as vital sign changes do not occur early, and signs of peritoneal irritation may be masked, altered, or delayed in children.

The majority of injuries to the abdominal and GU system are blunt injuries sustained in automobile crashes. The spleen and liver are most frequently injured, followed by the kidneys and gastrointestinal (GI) tract. A unique pattern of injury in small children (between 4 and 9 years of age) is lap belt complex. This pattern of injuries occurs when the lap belt portion of the seat belt is improperly positioned; the belt sits up on the abdomen of the child, and during a rapid deceleration the belt locks, compressing the abdominal organs. Associated injuries include small bowel contusions and/or lacerations, lumbar spine fractures, mesenteric hematomas, renal trauma, fractured pelvis, and ruptured bladder. The spleen is the most commonly injured solid organ in abdominal trauma in children. The child with splenic injury will complain of upper abdominal pain over the left quadrant, left shoulder pain (Kehr's sign), and possibly left chest pain. Hepatic injuries are common in children due to the size and prominent location of the liver. Although splenic injuries are more common, hepatic injuries have the highest mortality. The symptoms of liver injury include right upper quadrant pain and tenderness.

The second most common cause of abdominal trauma in children is pedestrian injury. Additionally, a small number of children sustain abdominal trauma when falling from heights. In

children younger than 2 to 3 years of age, abusive injuries account for a significant portion of abdominal trauma. These injuries occur when the abdomen is compressed following a kick or a punch. When the organs are compressed, bowel wall rupture can occur, leading to peritonitis and massive intraabdominal bleeding. Children who survive these injuries should be reported to the local child protective services organization because other forms of abuse may often be present.

School-age children sustain abdominal trauma when riding their bicycles, with the most severe injuries occurring when the child strikes the handlebars. Traumatic pancreatitis is a common injury occurring with handle bar related injuries. The mean delay to treatment for traumatic pancreatitis in one study was 23 hours. Only after the children demonstrated signs and symptoms did their families seek medical attention.

Penetrating injuries account for only a small amount of abdominal injuries. However, with the increasing incidence of gun violence, the incidence of penetrating trauma has increased annually. This type of trauma is more commonly identified in children older than 12 years of age and is more common in male patients than female patients.

## **MUSCULOSKELETAL AND SOFT TISSUE TRAUMA**

The majority of traumatic injuries sustained by children are orthopedic injuries. Fortunately, children have the distinct advantage of rapid bone growth, leading to faster healing. The thick periosteum in children allows for less fracture displacement, fewer open fractures, and more stability of fractured extremities.

The type of injury sustained is commonly identified by the mechanism of injury. Falls onto outstretched arms, such as falling off of monkey bars, cause fractures and/or dislocation of the upper extremities. Fractures of the lower extremities are associated with falls from heights (if the child lands on his or her legs) or are often sport related fractures. Obtaining an accurate history of the mechanism of injury will prevent the EMT from missing undetected injuries. Accurate assessment of orthopedic trauma can be hampered when a child is in pain.

The 5 P's of assessment provide a useful mnemonic device for assessment. The patient should be assessed for:

- Pain
- Pallor
- Pulselessness
- Parasthesia
- Paralysis

When assessing a child, it is wise to begin on the uninjured side, working toward the injured extremity. Beginning assessment at the most distal point from the injury and working toward the suspected site of injury will allow for more in depth assessment of the child. The most common

fractures in children are fractures of the forearm and clavicle. Both fractures occur when a child falls onto an outstretched arm.

Femur fractures require a tremendous amount of force. Children sustain these types of fractures most commonly in automobile accidents. The major concern following these injuries is the risk of hemorrhage associated with significant vascular injury. Unless stabilized, the child can exsanguinate following a femur fracture.

Another life threatening fracture is a pelvic fracture. Although rare in children, the risk of death with these injuries is high. Pelvic fractures in children are secondary to compression type forces, causing displacement of the pelvic ring and injury to surrounding organs and vasculature. Eighty percent of pelvic fractures that have multiple fracture sites have associated abdominal or GU trauma. Ruptured bladder is common, especially in the child who had a full bladder at the time of injury.

## **SUMMARY**

Rapidly assessing and managing children with multi-system injuries is critical to their successful recovery. While new drugs, interventions, and diagnostic tools are on the horizon, the basics of trauma resuscitation must be adhered to in order to prevent death and disability in children.

Children are at increased risk of multisystem injuries, as the traumatic forces are distributed over a smaller body mass. The risk of death increases with these multisystem injuries. Head injuries remain the leading cause of death due to trauma in children. Initially, the tenets of trauma management include stabilization of the airway, breathing, and circulation. After these are secured, a head-to-toe assessment to identify all potential injuries must be undertaken. Throughout resuscitation, astute observation of the child's response to therapy must be performed; deterioration in the child's status is a poor prognostic sign. Healthcare providers caring for pediatric trauma victims are well aware of the benefits of injury prevention strategies. Supporting public awareness and education regarding these strategies whenever a child is seen can help further reduce death and disability from trauma in children.

Pediatric trauma care knowledge is a critical part of any healthcare provider's education when working in the emergency and trauma care fields. Instituting the measures presented in this course will enhance the care provided to victims of pediatric trauma.