Care of the Pediatric Trauma Patient

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- Complete the questions at the end of the course.
- Return your completed Evaluation to NetCE by mail or fax, or complete online at www.NetCE.com. (If you are a physician or Florida nurse, please return the included Answer Sheet/Evaluation.) Your postmark or facsimile date will be used as your completion date.
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Faculty

Susan Engman Lazear, RN, MN, received her undergraduate education at the Walter Reed Army Institute of Nursing in Washington, D.C. After completing her BSN, she served as an Army Nurse at Letterman Army Medical Center in San Francisco for four years. She then attended the University of Washington School of Nursing and received a Master's in Nursing, specializing in Burn, Trauma and Emergency Nursing. After receiving her MN, she started Airlift Northwest, the air ambulance service based in Seattle which serves the entire Northwest region, including Alaska. Mrs. Lazear left the air ambulance service to start her own nursing education and consulting business, Specialists in Medical Education. For the past 20 years she has been teaching emergency nursing courses throughout the country. She lives in the Seattle area. Mrs. Lazear continues to teach and publish. She is both an editor and contributing author of Critical Care Nursing, published by W.B. Saunders Company, in June of 1992. She served as an author and reviewer of the Emergency Nursing Core Curriculum 6th Edition, published by W.B. Saunders Company in 2007. She has been named to the Who's Who in American Healthcare list annually since 1992.

Faculty Disclosure

Contributing faculty, Susan Engman Lazear, RN, MN, has disclosed no relevant financial relationship with any product manufacturer or service provider mentioned.

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Division Planners/Director Disclosure

The division planners and director have disclosed no relevant financial relationship with any product manufacturer or service provider mentioned.

Audience

This course is designed for all healthcare professionals involved in the care of pediatric patients, especially those in trauma care centers.

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Special Approvals

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The purpose of NetCE is to provide challenging curricula to assist healthcare professionals to raise their levels of expertise while fulfilling their continuing education requirements, thereby improving the quality of healthcare.

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Disclosure Statement

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Course Objective

As injury remains a leading cause of mortality and morbidity among children, the purpose of this course is to allow healthcare professionals to provide timely care to pediatric trauma patients and to assist parents and caregivers in recognizing measures that prevent this type of injury.

Learning Objectives

Upon completion of this course, you should be able to:

1. Describe the impact of pediatric trauma on society and health care.
2. Describe the types of pediatric injuries sustained with a given mode of trauma, and identify the most common injuries occurring in various age groupings.
3. Identify unique anatomic or physiologic differences in children, when compared to adult patients.

4. Describe the levels of pediatric trauma care and how to prepare an emergency department for treatment of the injured child.
5. Discuss the components of the primary survey of a pediatric trauma patient.
6. Outline the secondary survey, and identify contro-versies in pediatric shock trauma management.
7. Differentiate between mild, moderate, and severe head injuries that may occur in pediatric patients.
8. Describe the unique traumatic injuries to the spine that occur in children and measures to treat these injuries.
9. Differentiate the types of cardiothoracic trauma, and list appropriate management for each type.
10. Identify the signs, symptoms, and management of pediatric abdominal and genitourinary trauma.
11. Recognize the risks and appropriate interventions in the management of orthopedic pediatric trauma.
12. Discuss the appropriate management of traumatic amputation and soft tissue trauma in pediatric patients.
13. List the signs and symptoms and appropriate interventions for post-traumatic respiratory distress syndrome in children.
14. Describe the identification and treatment of multiple organ dysfunction syndrome (MODS).
15. Differentiate the various types of renal failure that occur following trauma in the child.
16. Outline the role of interpreters when caring for patients whose families speak a language other than English.

EVIDENCE-BASED PRACTICE RECOMMENDATION

Sections marked with this symbol include evidence-based practice recommendations. The level of evidence and/or strength of recommendation, as provided by the evidence-based source, are also included so you may determine the validity or relevance of the information. These sections may be used in conjunction with the course material for better application to your daily practice.

INTRODUCTION

Trauma is the primary cause of mortality and morbidity in the pediatric population [1; 2]. 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 largely 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 a leading cause of injury and death among children in the United States [2].

Mechanisms of injury vary by age group. Drowning and water injuries are the second leading cause of death for children 5 to 9 years of age (number one for infants and toddlers), while suicide by suffocation ranks first and suicide by firearm ranks third among children 10 to 14 years of age [3]. Other forms of intentional violence, poisonings, sexual assault, and maltreatment are also common causes of trauma and fatality in the pediatric population [1; 2; 3]. The economic burden of injuries in children and adolescents is considerable and further exacerbated when factoring in the lifetime costs involved in treating and caring for these patients [3; 4].

The pediatric population accounts for approximately 28.4 million visits to emergency departments each year [5]. Of the pediatric patients treated in hospitals, the mortality rates vary. One study found that pediatric units within adult hospitals had the highest mortality rate at 2.4%. The lowest mortality rates were found in pediatric centers, which had a 0.9% mortality rate. The length of hospital stays in these different facilities mirrored these findings [6]. According to a survey by the CDC, 87% of hospitals with 24-hour emergency departments admit pediatric patients but only 40% have wards specifically for these patients, have a pediatric intensive care unit, or are a children's hospital [7].

Although the statistics remain sobering, it is important to remember that pediatric trauma care has made a significant improvement in the outcomes of these injured children. Due to the implementation of rapid field resuscitation and early transport to a center specializing in pediatric trauma care, the overall mortality rate due to traumatic injury is approximately 8% [8].

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. This course will focus on the patterns of childhood trauma and measures to reduce the mortality and morbidity of these devastating injuries.

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 sequelae of trauma, including multiple organ failure and post-traumatic respiratory distress syndrome. The risk of death and disability remains high throughout the first two weeks after injury. Although the child may survive this two-week stretch, 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 [4]. 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 and unintentional strikes are leading mechanisms of injury but are rarely a cause of death, while unintentional suffocation (i.e., choking, strangulation, asphyxiation) and homicide are the leading causes of mortality in this age group [3]. 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 not properly secured or is left unattended and inadvertently tips the carrier [9]. Children at this age may be unrestrained in a MVA and suffer significant multisystem injury. Fatal child abuse, particularly abusive head trauma, is also prevalent at this age.

Toddlers (1 to 3 years of age) and preschoolers (3 to 6 years of age) are most likely victims of drowning or motor vehicle trauma, both as passengers and as pedestrians [3]. 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, and burns occur when children are unattended and encounter danger that they cannot defend themselves against nor comprehend. The toddler and preschooler may also be victims of abuse and homicide.

As noted, 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 63% to 88% [10]. Advances in helmet designs are further reducing the incidence of traumatic brain injury as a result of bicycle accidents [11].

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 [3]. 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 non-Hispanic black individuals 15 to 19 years of age have the highest proportion of homicide deaths, frequently precipitated by firearms [12].

The suicide rate in teenage individuals increased threefold between 1950 and 1990; it began to decrease in the late 1990s, but since 2000 the incidence has increased annually [3; 13]. Suicide is the second leading cause of death for children 10 to 14 years of age and adolescents 15 to 24 years of age [3]. In 2015, adolescents and young adults 15 to 24 years of age had a suicide rate of 12.5%, with the highest rate (15.1%) among white youths [13]. Native American/Alaskan Native youths had the second highest rate for suicide deaths [13]. Hispanic youths are more likely to attempt suicide than non-Hispanic black or white children.

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 1,400 agents available over the counter that can be legally purchased by young teens as a method of getting high [14].

An emerging area of research in trauma epidemiology is the impact of sports-related 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 [3]. 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, one study showed that the inability to communicate was not associated with an increased incidence of missed injury [15]. The prevalence of missed injuries among pediatric trauma patients has varied among studies, from 1% to 18% [16]. 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?" As previously discussed, the patterns of injury are influenced by a number of factors. 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 [2]. 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 [17]. 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. As noted, 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. There are more than 100 different car seat designs, 40 types of seatbelts, and 300 types of cars in which these seats are installed. It is no wonder that there is disparity in how well the seat is secured. Canada and many European countries have a universal system for installation; this universal locking mechanism was required in all vehicles sold in the United States after September 2002. In 2011, the American Academy of Pediatrics updated their recommendations concerning safety seat selection and use. Small children should be placed in rear seats and facing backward until they are at least 2 years of age or have reached the top height or weight bracket recommended by the seat manufacturer [18].

An additional type of vehicular trauma in pediatric patients occurs in school-age children riding on school buses. Between 2009 and 2018, there were 249 school-age children killed in school-transportation-related crashes; 52 were occupants of school transportation vehicles, 92 were occupants of other vehicles, 100 were pedestrians, and 4 were cyclists. Fifty-two percent of the school-age pedestrians killed were 5 to 10 years of age [19]. Between 2009 and 2018, nearly half (48%) of the school-age pedestrians killed in school-transportation-related crashes were struck by school buses or vehicles functioning as school buses [19].

In recent decades, there has been conflicting information regarding the necessity and effectiveness of seat belt use on school buses. In a 2002 report to Congress, the National Highway Traffic Safety Administration (NHTSA) stated that the use of seat belts on large school buses (>10,000 lbs) appear to have little, if any, benefit [21]. In addition, they add considerable cost and limited seating capacity [21]. The NHTSA poses that larger buses are designed with high seat backs that are close together and these seat backs are designed to safely absorb impacts, creating a compartment of safety for passengers [22]. In 2015, the NHTSA for the first time endorsed the use of three-point seat belts on large school buses but did not specifically recommend requiring them [23; 24]. Recommendations from the NHTSA indicate that compartmentalization on large buses is adequate for safety, although seat belts are not prohibited. To the contrary, in 2018, the National Transportation Safety Board (NTSB) recommended that all states "enact legislation to require that all new large school buses be equipped with passenger lap/shoulder belts for all passenger seating positions" [20]. As of 2020, eight states (Arkansas, California, Florida, Louisiana, Nevada, New Jersey, New York, and Texas) have laws requiring the installation of seat belts on school buses [20]. As of 2008, federal law requires small buses (<10,000 lbs) to be equipped with lap and/or lap/shoulder belts at all designated seating positions [22].

During the teenage years, an additional type of injury that occurs as a result of an automobile occurs when a teen is "car surfing" [25]. 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 or "skitching"). 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, approximately 250,000 children and adolescents are injured while riding bicycles and 120 die [3]. Bicycles are the leading cause of mild traumatic brain injury (MTBI) in children [26]. 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 in-line 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 [27]. 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 [26]. While football is the leading cause of this type of injury in men, soccer is the leading cause for women [26]. After bicycling, football, basketball, playground recreation, and soccer are the leading causes of TBI in children 5 to 18 years of age [26]. The American Academy of Neurology has set guidelines for player assessment and return to play, stating that no athlete should return to play before being evaluated by a properly trained physician or neurologist; unfortunately, these guidelines are overlooked in some cases, and a player is returned to play sooner than would be prudent [28]. 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 [29]. 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 [27; 30]. Studies show that considerable cognitive decline occurs in players who have incurred subdural hematomas and other types of head trauma [31; 32; 33]. 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" [30]. More research is needed to identify new measures of minimizing injuries. Educating athletes, families, and coaches on the dangers, prevention, and management of football-related injuries is also crucial.

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 in the long-term remains controversial, although studies have shown that measurable transient cognitive impairment is present [29]. A 2016 study showed an increase in corticomotor inhibition immediately after heading, causing electrophysiologic alterations that led to measurable reduction of memory function for up to 24 hours [122]. Another study published in 2018 found that heading was more strongly related to cognitive impairment than unintentional head impacts, suggesting that efforts to reduce long-term brain injuries may be focusing too narrowly on preventing accidental head collisions [123]. Several leading organizations have also conducted research in this area, but no recommendations have been made [29].

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 [34]. However, snowboarders suffer an increased number of upper extremity injuries. Injuries to the wrist are the most common trauma sustained while snowboarding [34].

Personal watercraft-related injuries are more prevalent than injuries from all other water sports [35]. Common injuries associated with these activities include trauma to the head, face, chest, spine, and abdomen [36].

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.

PEDIATRIC TRAUMA RESUSCITATION

Resuscitation of the pediatric trauma patient requires not only hands-on care, but also recognition of the multitude of intricacies that the pediatric patient brings to the resuscitation. Anatomic and physiologic differences between children and adults require that interventions be altered to take these differences into account. Preparing the emergency department for a pediatric trauma victim requires pediatric-specific equipment and personnel trained in pediatric advanced life support measures. Instituting the primary and secondary survey must be done with these conditions in mind. Finally, adequacy of resuscitation must be monitored with consideration of the child's normal level of functioning. Controversies in pediatric resuscitation continue. Therapies are, and should be, evaluated on a regular basis as a method of improving future care.

ANATOMIC AND PHYSIOLOGIC DIFFERENCES

Trauma resuscitation of the pediatric patient requires that the practitioner be cognizant of the uniqueness of children's anatomy and their physiologic needs. Comparison of the child's anatomic and physiologic parameters to those of an adult patient demonstrates that children are not merely small adults, and interventions must be varied to meet these subtle differences.

Children have relatively larger heads that can be frequently injured in trauma. Proportionately, there is a larger volume of blood in the head, leading to the rapid onset of cerebral edema and increased intracranial pressure (ICP). Very young children, younger than 2 years of age, have soft bones and cranial suture lines that are not completely fused. This predisposes children to diastatic fracture, a separation of the cranial bones at the suture line. Injuries to the neck and spinal column of a child occur for two reasons: the head is heavy, and muscular support of the neck is poor, leading to flexion and/or extension injuries. Often, the child will present with neurologic deficits without radiologic abnormalities, defined as spinal cord injury without radiologic abnormality (SCIWORA).

Stabilization and management of the child's airway is more difficult because the larynx is more cephalad and anterior than an adult's, resulting in vocal cords that are more difficult to visualize during an intubation attempt. In addition, the child's airway diameter is narrow, which can lead to the rapid onset of airway loss with only mild edema formation. With the onset of edema formation, airway resistance increases, causing the child to have a more difficult time maintaining an adequate gas exchange.

The respiratory system of a child is small, with less alveolar surface area for gas exchange and fewer collateral ventilatory pathways. Parenchymal injury, such as a pulmonary contusion, leads to severe rapid compromise if oxygen and ventilatory support are not provided early during the resuscitation. The anatomic variables in a child's chest include horizontal ribs and diaphragm, more cartilaginous sternum and ribs, a thin chest wall, and a thin diaphragm. A child may sustain massive injury to the chest without signs of external trauma (e.g., rib fractures, sternal fracture, etc.).

An increased susceptibility to both vagal and sympathetic stimuli leads to wide ranges in the child's pulse rate. In addition, children may be tachycardic for a number of reasons, including pain, fear, and agitation, so the assessment of tachycardia is less beneficial. The heart of a child is more cephalad in the chest cavity and has a thin endocardium and small pericardial sac; therefore, it is more prone to blunt injury to the chest. The development of cardiac tamponade can be rapid and severe, leading to early cardiac arrest if not identified and treated expeditiously.

A thin-walled abdomen without musculature to protect the abdominal organs leads to frequent rupture of these organs. In addition, the horizontal diaphragm does little to protect the liver and the spleen from injury. With fewer fat deposits around the abdominal and retroperitoneal organs, the organs are at risk for developing tears of the major vessels supplying them. Once injury has occurred, bowel sounds are of little value as bowel function is labile and bowel tones are frequently absent regardless of the extent of injury. The size of the abdominal organs is proportionately larger, with the exception of the stomach, which is small with a small capacity. Stomach distention leads to upward displacement of the diaphragm, causing respiratory distress.

Musculoskeletal injuries account for a significant percentage of the traumatic injuries seen in children. The bones are soft and pliable, leading to multiple fracture types. Healing of fractures occurs rapidly secondary to the thick and highly vascular periosteum. The incidence of dislocations is reduced because ligaments are proportionally stronger.

Renal function is not well developed, and functional reserve is decreased, causing the injured child to produce dilute urine and be at risk for acute renal failure. The genitourinary (GU) organs sit high in the intra-abdominal cavity, outside the pelvic ring, which increases the risk of injury to these organs.

Other unique parameters in children include the large body surface area to body mass, leading to an increased risk of hypothermia at the time of injury as well as during the resuscitation. Children have irregularly functioning sweat glands, increasing the susceptibility to temperature variations. In addition, the immune system is not completely developed, putting the child at a relatively high risk for infection. Also, the proportion of body water to body weight decreases as a child grows, causing the small child to be at risk for developing dehydration.

Vital signs vary by age, and it is important to know the "normals" for each individual child. This basic knowledge of the child will allow the physician and team managing the pediatric patient to recognize changes in the child's status. However, it should be noted that vital sign changes alone can be misleading and lead to delayed interventions.

Finally, when assessing the injured child, growth and developmental characteristics must be considered. These capabilities will depend in part upon extrinsic factors, such as older siblings and school attendance. As a child develops, growth proceeds from head to toe, proximal to distal, and gross to fine direction. However, many of the child's capabilities will regress when the child is ill or injured.

In summary, it is imperative to consider the unique parameters of children when resuscitating and stabilizing the injured child. Interventions may require alteration from standard trauma protocols to adjust to the individual child's needs. To review some of the important variances of children and the significance to trauma care, refer to ***Table 1***.

UNIQUE PEDIATRIC PARAMETERS AND SIGNIFICANCE TO TRAUMA CARE	
Variable	**Significance**
Large volume of blood in head	Cerebral edema develops rapidly
Poor muscular support of neck	Flexion/extension injuries occur
Narrow airway diameter	Increased airway resistance
Less alveolar surface area	Injury leads to rapid respiratory compromise
Heart lies higher in chest cavity	Prone to injury
Thin-walled, small abdomen	Organs not well protected
Bones are soft and pliable	Fractures are less common but still occur
Renal function not well developed	Acute renal failure develops easily
Large body surface to body mass	Prone to hypothermia
Source: [37]	*Table 1*

OVERVIEW OF EMERGENCY PEDIATRIC TRAUMA CARE

LEVELS OF PEDIATRIC TRAUMA CARE

Most children who are injured are treated first by paramedics in the field when a call goes into the local 911 center. The child is then transported to a definitive healthcare facility for resuscitation and stabilization. Pediatric trauma systems have been developed throughout the United States to ensure that the pediatric trauma victim is receiving the optimal care available.

Studies have shown that the level of care provided at sophisticated trauma centers reduces the risk of death in seriously injured children. A differentiation is made between pediatric trauma centers and trauma centers with pediatric commitment. A pediatric trauma center is capable of not only providing tertiary medical care but also support services that are designed specifically for the pediatric patient. In adult trauma centers with pediatric commitment, the special needs of children may or may not be met at the same level as they are at pediatric trauma centers. However, the availability of these centers is limited. The vast majority of pediatric trauma victims are cared for in hospitals without specifically designated pediatric trauma centers [6].

One important determinant in the outcome of children with traumatic injuries is the training of healthcare providers in pediatric trauma care management. Those facilities with ongoing continuing education and a commitment to current trauma therapeutics demonstrate better outcomes for children when compared to a general hospital emergency department. Another interesting statistic showed that only 5% to 21% of children with blunt spleen and liver trauma cared for by pediatric trauma surgeons undergo laparotomy. When compared to children cared for by adult trauma surgeons, the incidence of laparotomy increased to as high as 53% to 58% [38]. Despite the trend toward nonoperative management of these injuries, there remains a significant disparity in how pediatric patients are managed.

Other methods that are utilized to determine the level of care required by the pediatric trauma victim include scoring systems. These systems are designed to improve triage, organize trauma care, predict mortality and morbidity, and assure quality care. No ideal scoring system exists, yet many facilities will use these scores as determinants of pediatric care. One of the most widely utilized scoring systems in the prehospital setting is the Pediatric Trauma Score, which assists the prehospital care provider in determining when a child should be transported to a hospital with a high level of sophisticated equipment. Other scores that analyze severity of injury, such as the Abbreviated Injury Scale and the Injury Severity Score, may be utilized to identify children at high risk for adverse outcomes.

Knowledge of availability of resources for pediatric trauma victims is an important aspect of managing the injured pediatric patient. Facilities must be willing to conduct self-examinations to determine their level of commitment and transfer those patients who cannot be cared for within the constraints of their facility. Managing the pediatric trauma victim with minimal resources increases the risk of death and disability. Prevention of this mortality and morbidity should be foremost in the minds of healthcare providers in determining appropriate care for the injured child.

PREPARING THE EMERGENCY DEPARTMENT FOR A PEDIATRIC TRAUMA PATIENT

Readiness for resuscitation of the pediatric trauma victim requires a number of steps. Not only must the physical requirements of the child be met, but the emotional, psychologic, and social demands should also be weighed. Care providers must be able to intervene in all these realms to ensure family-centered care.

Physically, the department should be prepared with the equipment of appropriate size to meet the special requirements of the young patient being admitted. The Committee on Pediatric Emergency Medicine prepared a list of recommendations for equipment to be available for treating pediatric patients [39]. Often, the report from the prehospital personnel will provide the age of the child, which allows an estimation of the size and weight. Although formulas for estimation exist, the use of the Broselow tape is now recommended to ensure age and weight-appropriate interventions. Immediate weighing of the child upon admission is not critical in the case of the trauma patient because appropriate estimation can be achieved utilizing this method. When the patient is stabilized, an accurate weight can be obtained.

Personnel trained in pediatric trauma resuscitation should be notified and present at the bedside upon arrival of the patient in the emergency department. A pediatric resuscitation cart should be readily available to provide the appropriate size equipment for the patient. A cart that is color coded to match the Broselow tape can be helpful in expediting equipment acquisition.

Social workers, clergy, or other personnel can provide excellent support to the family. These individuals should be trained in providing general information on what is being done for the patient and how long it may be before the family members can visit with the child. Specific information regarding injuries and outcomes should be provided at the discretion of the attending physician; however, availability of general information will go a long way in helping the family adjust to the situation at hand.

The medical, nursing, and ancillary staff must be prepared to deal with the psychologic impact of caring for the pediatric trauma patient. Children may be injured as a result of activities that the staff does not condone (lack of seatbelt use, abusive injuries, lack of supervision), and feelings of frustration and anger must be restrained while resuscitating the child and dealing with the family. If an extremely emotional case occurs in the department, postresuscitation debriefing may benefit all those who cared for the patient.

PRIMARY SURVEY

In 2010, the American Heart Association (AHA) resuscitation guidelines changed from an airway, breathing, and compressions sequence to a compressions, airway, breathing (CAB) sequence for both adults and children; this was reaffirmed in updated 2020 AHA guidelines [40; 124]. In the trauma scenario, this means checking for a pulse and starting external cardiac compressions if one is not felt, before turning attention to the airway, while simultaneously determining if the child has sustained any life-threatening injuries. Major exsanguinating hemorrhage, including hemorrhage resulting from pelvic fractures, should be controlled as a matter of urgency, at the same time as assessment of the airway [41]. 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 airway, breathing, and circulation (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 starts at the injury scene and aims to ensure a patent airway, adequate breathing, and circulatory support and to assess major neurologic disability. Although the primary survey should take no longer than 5 to 10 minutes for assessment and stabilization, it also should include frequent reassessment to confirm or exclude injuries that require immediate surgical intervention [41].

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 [41]. 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.

For the child who is unable to maintain a patent airway, endotracheal intubation via the orotracheal approach should be instituted. The appropriate size tube should be utilized. Anatomic differences between adult and pediatric airways make endotracheal intubation more challenging in the child. During trauma resuscitation, the care provider with the most experience at pediatric intubations should be assigned the responsibility of securing the airway. It is strongly recommended that those with less experience should defer this responsibility.

Rapid sequence intubation (RSI) has become a recommended adjunct to airway management of the child considered at high-risk of complications secondary to intubation. RSI involves the administration of sedative and paralytic agents to improve the success of intubation and reduce the risk of intubation increasing ICP. The methods of RSI vary slightly, and different trauma programs may choose different drug combinations [42]. There has been some discussion about where and when RSI should be used, but most authorities are in favor of the technique [43; 44]. The American Heart Association recommends that RSI be used only by trained personnel who are experienced in administering the medications and proficient in the evaluation and management of the pediatric airway [40]. ***Table 2*** lists the seven steps in securing the child's airway utilizing rapid sequence intubation techniques.

One technique that improves success and decreases the risk of complications during intubation is performance of the Sellick maneuver. To perform this maneuver, the assistant places his/her fingers over the trachea at the level of the cricoid ring and places firm pressure in an anteroposterior direction. This will displace the trachea posteriorly, closing off the opening to the esophagus. The individual who is performing the intubation will be able to better visualize the vocal cords, thus improving the chances for a successful first attempt intubation. Additionally, by closing off the esophagus, the risk of aspiration is decreased should the patient regurgitate during the intubation attempt. It is critical that the individual performing this Sellick maneuver not place too much pressure on the airway, as the trachea is collapsible and devastating loss of airway can occur [42]. The correct pressure is equivalent to the amount that would begin to be painful when depressing the bridge of the nose [47].

Injuries that may complicate airway management include those of the face, including facial fractures, mandibular fractures, and fractures of the maxilla.

RAPID SEQUENCE INTUBATION PROTOCOL FOR CHILDREN (THE SEVEN Ps)	
Aspects of Intubation	**Sequence of Events**
Preparation	Ensure adequate IV access (preferably two IV lines). Test suction and oxygen equipment. Prepare endotracheal tube (ETT) (check cuff patency). Assemble equipment (e.g., drugs prepared in syringes, laryngoscope ready). Initiate pulse oximetry, if not already done. Optimize the patient's position for intubation access. Assess for possible difficult airway.
Preoxygenation	Apply 100% oxygen for five minutes of normal breathing. If time does not permit, administer eight vital capacity breaths (maximum volume patient can take) with 100% oxygen.
Pretreatment	Consider atropine 0.01 mg/kg IV. Consider lidocaine 1.0–1.5 mg/kg IV in patients with severe reactive airway disease or patients with increased ICP. Consider administering a rapid fluid bolus to mitigate the hypotensive effect of anesthesia.
Paralysis and induction	After two minutes of last pretreatment drug, administer sedative/anesthetic and neuromuscular blocking agent/paralytic. Sedative/anesthetic choices may include (usually only one is administered) sodium thiopentone (5–8 mg/kg), propofol (2.5 mg/kg), ketamine (1–2 mg/kg), or midazolam (0.1–0.2 mg/kg). Administer rocuronium (0.6–1.2 mg/kg). Succinylcholine is not recommended for children.
Protection and positioning	As patient loses consciousness, perform the Sellick maneuver (i.e., cricoid pressure) and maintain this position until ETT is in place and cuff is inflated. Maintain in-line stabilization. A neutral position is acceptable if cervical spine injury is suspected, but in its absence, the "sniffing" position is preferable, as it brings the axes of the larynx, pharynx, and mouth into alignment.
Placement with proof	Approximately 45 seconds after administration of the paralytic agent, proceed with intubation. Inflate cuff and confirm tube placement.
Post-intubation management	Secure tube, measure and report blood pressure and other vital signs, and initiate mechanical ventilation. Continue long-term sedation/paralysis/analgesia, as indicated.
Source: [45; 46; 47]	*Table 2*

These injuries produce rapid swelling and the visual loss of anatomic structures. Although needle cricothyrotomy is avoided in most cases, these injured children may require securing the airway utilizing this method. (Routine surgical cricothyrotomy should not be performed on children.) Emergency tracheotomies should only be performed in the operating room under controlled conditions. Field and emergency department management of the airway should first include intubation with RSI, and if unsuccessful, laryngeal mask airway placement or needle cricothyrotomy.

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. Ideally, chest compressions should be immediately started by one rescuer, while a second rescuer prepares to start ventilations with a bag and mask. Ventilation is critical in pediatrics due to the large percentage of asphyxia arrests in which best results are obtained by a combination of chest compressions and ventilations [40].

Choosing the appropriate size resuscitation bag (bag valve mask) is critical to prevent overdistention of fragile lung tissue [40]. 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 [40; 41].

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 [40]. 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. The most common complications of IO line placement are the development of a local abscess or cellulitis at the insertion site and osteomyelitis. Both complications may be treated with antibiotics.

MAINTENANCE FLUID ADMINISTRATION PROTOCOL
100 mL/kg for 1st 10 kgs 50 mL/kg for 2nd 10 kgs 20 mL/kg for each kg over 20
Example: 20 kg child 1,000 mL for first 10 kgs 500 mL for second 10 kgs Total: 1,500 mL/24 hours Rate of administration: 62 mL/hour Fluid of choice: D5 0.25% normal saline
Source: Compiled by Author *Table 3*

Volume replacement in children is based on a milliliter per kilogram basis with initial resuscitation started at 10–20 mL/kg with warmed IV fluid. This fluid is administered rapidly and the child monitored for adequacy of resuscitation. In the child with ongoing blood loss, IV fluids can be increased to 50–60 mL/kg; however, at this point, blood administration should be considered. Whole blood is administered at 20 mL/kg, while packed red blood cells can be administered at 10 mL/kg diluted with an equal amount of normal saline.

The choice of IV fluids is somewhat controversial. Both lactated Ringer's (LR) solution and normal saline (NS) solution may be administered as the initial crystalloid for resuscitation. Additionally, children will require the administration of a dextrose-containing solution, preferably D5 0.25% NS, to prevent the development of hypoglycemia and acidosis. This dextrose containing solution is commonly referred to as maintenance fluid and is administered in children younger than 8 years of age on a mL/kg basis. ***Table 3*** presents the formula for maintenance fluid administration.

Throughout the resuscitation, efforts at maintaining normothermia and normal blood glucose levels should be undertaken. Resuscitation requires a team approach with individuals assigned specific tasks to support the child during this critical time period. Although discussed as a step-by-step sequence, simultaneous stabilization is mandatory.

After the ABCs are stabilized and ongoing resuscitation efforts are secured, the child must be assessed for the level of disability. A rapid method of disability evaluation is to utilize the AVPU mnemonic. A is for alert, V indicates the child responds to verbal stimuli, P indicates response to pain, U is for the unconscious patient.

Prior to initiating the secondary survey, the child must be completely undressed and all body surfaces exposed to allow for identification of underlying injuries.

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 physician 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 fontanelles should be palpated 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 neurologic pathway. Evaluation of the corneal and gag reflexes should be obtained as part of the neurologic assessment. Motor and sensory function should be evaluated.

The neck should have been secured in a hard collar by prehospital personnel. At this point, the collar may be removed while an additional person ensures neck alignment. The neck is assessed for deformity, swelling, and pain. Range of motion should not be assessed until a clear cervical spine x-ray has been obtained.

The chest is evaluated for bilateral, symmetrical chest movements with ventilation. Auscultation should include assessment of breath and heart sounds. Shoulder harness ecchymosis should be looked for if the mechanism of injury suggests this pattern of injury. Although pediatric rib fractures are rare, integrity of the rib cage must be determined. When the child reaches adolescence, the incidence of rib fractures increases.

The abdomen should be palpated. Any obvious injury should be assessed last. Beginning the assessment in a nonpainful area will ensure better cooperation from the child. Increasing abdominal distention is an early sign of underlying injury in a child and should be documented and followed as care progresses.

The extremities should be assessed for proper alignment and range of motion. Any obviously injured part should be left alone, but distal pulses should be obtained to ensure adequate distal circulation. While at times it is difficult to assess children's extremities, comparing the injured side to the uninjured side will improve the ability to recognize injuries.

After the anterior torso and extremities have been fully assessed, the child should be logrolled so the back and buttocks can be evaluated. Bruising over the flank area is an early sign of renal trauma and can only be identified if the child is evaluated both front and back.

Throughout this assessment the child should be continually monitored for response to therapy. Oxygenation and ventilatory status should be of prime importance. Vital sign assessment should be obtained and interventional changes based upon the most current findings. Cardiac monitoring, nasogastric tube, and Foley catheter placement can be initiated as appropriate. Once injuries have been identified, laboratory and radiology studies can be instituted. Specific studies are identified in the following discussions of system trauma.

A final step in the resuscitative process should be the institution of pain control and anxiety-reduction measures. Many physicians prefer to delay administering narcotics until the secondary survey is complete and all injuries have been identified. At this point, the child can be administered morphine (0.1 mg/kg) or fentanyl (1 mcg/kg) and midazolam (0.05–0.1 mg/kg) as needed [40; 46; 124]. Assessment of the effectiveness of these pain control measures should be performed. If the child continues to complain of pain, additional medications should be considered [48].

After all injuries have been identified and stabilized, a decision regarding further intervention must be made. The severity of injury may require that the child go directly to the operating room for further stabilization measures. Many pediatric traumatic injuries are managed nonoperatively, and the child can be admitted directly to the intensive care unit. Depending upon the capabilities of the institution, the appropriate disposition may be to transfer the child to a more sophisticated facility with pediatric trauma teams to further care for the child. Arranging for this transfer should be initiated as early as possible, and air transport may be considered to limit the out of hospital time to which the child is subjected [49].

CONTROVERSIES IN PEDIATRIC SHOCK TRAUMA MANAGEMENT

Many of the controversies in trauma management are identified in adult and animal models. Most of the information obtained in these populations is then postulated into the pediatric model. Thus, the available information regarding controversial interventions may or may not be of consequence in the pediatric trauma patient; only time and experience will tell.

Aggressive fluid resuscitation has been the protocol for many years, first being supported by the American College of Surgeons in the Advanced Trauma Life Support courses. However, there has been interest in what is known as "minimal volume, delayed resuscitation" in a specific group of patients. The rationale for this resuscitation technique is that maximum fluid resuscitation will increase bleeding, prevent clot formation, or dislodge forming clots. The use of this type of resuscitation is supported in patients with ruptured abdominal aortic aneurysms (a very rare injury in children) and in patients with penetrating truncal trauma (as seen in gunshot wounds). After the injuries have been stabilized and bleeding has been controlled, aggressive volume resuscitation is then initiated to restore normal hemovolemia.

The minimal volume, delayed resuscitation philosophy is at odds with the new standards of care for the patient with a head injury who requires an adequate blood pressure to ensure adequate cerebral circulation. In addition, this method of resuscitation is not recommended in the rural setting with long transport times because the patient may exsanguinate prior to reaching a higher level of trauma care.

As the incidence of penetrating truncal trauma increases in the pediatric population secondary to the increasing incidence of gunshot wounds, the use of minimal volume, delayed resuscitation continues to be evaluated. Because of small circulating volume, the pediatric patient may not benefit from this type of resuscitation in the same way as the adult trauma victim. However, resuscitation appears to improve outcomes, specifically in patients who require surgery [50]. It is also crucial that each patient's condition be assessed as a unique situation [51]. Further study must take place to interpret the effects of this type of therapy. At the present time, resuscitation with aggressive fluid infusion is currently recommended for management of pediatric trauma.

An additional area of debate in trauma resuscitation is how to best measure the effectiveness of resuscitation efforts. All patients should be monitored for adequate urine output, stable vital signs, and acceptable respiratory function. As these measurements are assessments of global functioning, the need to look at organ specific endpoints is also important.

One of the difficulties in assessing end organ function is how to best measure these parameters. High-tech interventions have been developed, but high tech often equates with expensive care. Methods for tissue oxygenation monitoring have been developed to provide more detailed information on organ function [52; 53]. With this information has come the need to develop methods of manipulating the end organ function and regulating tissue perfusion at this level.

Organ-specific monitoring has focused a great deal of attention upon the gastric system. The splanchnic bed is the area first affected by loss of volume and one of the last areas to regain adequate function once resuscitation is instituted. Measuring the gastric mucosal pH has been performed as an indicator of hypoperfusion. The technique is simple, and the calculations are easy to perform. In patients with low gastric pH, the incidence of multiple organ dysfunction syndrome (MODS) was increased and the mortality of critically ill patients was higher [54]. Efforts are now underway to refine methods of assessing gastric pH, manipulate the gastric pH, and determine what levels of pH are acceptable as goals of resuscitation [55; 56; 57]. There is much work to be done in this area, but it is an area of tremendous excitement as new information arises on how to assure adequate resuscitation and thus improve outcomes of trauma victims of all ages.

Despite the development of new techniques and interventions, the ultimate goal of resuscitation is to match energy production with energy demand at the cellular level. If global measurements (such as urine output) are the only measurements available, these should be followed and the child stabilized to meet the needs already identified.

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. TBI is a major cause of death and disability. According to the CDC, there are 2.87 million TBI cases per year in the United States, with approximately 30% occurring in children [58]. Children 15 to 19 years of age are also at risk for TBI [59]. In particular, treatment for sports- and recreation-related TBI has become more prevalent; the number of children and adolescents treated for nonfatal TBI resulting from sports or recreation activities increased significantly between 2001 and 2009, from 153,375 to 248,418, to an average of 283,000 during 2010–2016 [59; 125]. However, the CDC has reported that sports and recreation TBIs decreased 32% between 2012 and 2018, likely due to a decline in football-related TBIs. It was noted that increased public awareness of sports-related TBIs resulted in decreased participation in tackle football among children and adolescents, as well as implementation of contact limitations [125]. While this information is promising, prevention efforts for sports- and recreation-related TBI should continue and these strategies should be implemented for other sports with a high risk.

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 focus of this section will be primarily on injuries to the brain, concluding with a brief discussion of injuries to the facial structures, including the ocular system.

The majority of traumatic injuries affecting the head and face are a direct result of MVAs, falls, and sports activities. 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 [59].

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. Healthcare professionals have little control regarding the development of this type of injury, with the exception of education regarding prevention. Secondary injuries occur as a result of the trauma; examples include cerebral edema, bony fragments, and delayed vascular injury. Different portions of the brain demonstrate different responses to injury. For example, the area of primary trauma may exhibit vasospasm, while another area may develop vascular leak as a result of secondary 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. In acute situations, hemostats and ligation or cautery of scalp vessels may be required to staunch the ongoing blood loss.

A pattern of injury that may be of concern to parents is the development of a cephalohematoma as the result of bleeding and swelling between the scalp and the skull. This form of injury, if isolated, is treated with observation and follow-up until resolution is achieved, which may require several weeks. However, it is critical that during this recovery period assessments are performed faithfully to rule out any delayed onset of TBI.

Skull fractures are described by their type: linear, depressed, compound, basilar, ping-pong ball, and growing. Seventy-five percent of pediatric skull fractures are linear fractures, or simple cracks in the bone [60]. If no underlying injury develops, the child will have complete resolution of the fracture site. Over time, this fracture line may completely disappear from x-ray as remodeling of the skull occurs.

Depressed fractures cause disruption of the integrity of the skull. The depth of the depressed segment correlates with the extent of injury; the deeper the depression, the greater the risk of underlying traumatic injury to the cranial contents. It is recommended that any child sustaining a depressed injury undergo a head computed tomography (CT) scan or possibly magnetic resonance imaging (MRI) to fully evaluate the extent of injury. A tear in the dura will increase the risk of infection and post-traumatic seizure development.

Compound fractures complicate the diagnostic process because multiple bony fragments must be evaluated. Each fracture segment must be assessed for depression and disruption of the dura mater. Creation of a compound fracture requires a tremendous application of external force to the skull. Suspecting nonaccidental trauma (such as child abuse) should be a consideration when caring for the child sustaining this type of injury.

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 hemotympanum. 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. This ecchymosis is commonly associated with a fracture of the temporal bone. Any fracture occurring at the base of the skull can be accompanied by injury to the ocular, cochlear, and facial nerves, leading to concomitant loss of vision, hearing, or facial muscle function. Furthermore, these fractures are considered to be open, allowing introduction of organisms into the cranial vault with subsequent risk of meningitis development.

Two types of skull fractures are unique to the pediatric trauma victim. The "ping-pong ball" fracture is a dent in the skull; the segment is depressed but no fracture lines are evident on x-ray. The "ping-pong ball" designation was coined when someone noticed that the appearance of this type of fracture is similar to that of a ping-pong ball when it is indented. This type of fracture is only seen in small children, generally younger than 2 years of age, due to the minimal mineralization of the skull. The inherent risk of this depressed segment is the underlying damage to the cranial tissue. The depressed segment is commonly surgically elevated to reduce its impingement into the cranial vault and to prevent the formation of cosmetic deformities.

Another unique skull fracture in children is the growing fracture, also known as a leptomeningeal cyst. This type of fracture occurs when the dura is torn and there is accumulation of CSF in the extradural space. If this cyst develops, the fracture site appears to be growing as the cyst increases in volume. Over time, if not recognized and treated, the cyst can enlarge to the point of producing brain tissue compression. Obscuring the diagnosis is the inability to visualize the dura on plain skull radiographs. MRI is the best method for dural integrity evaluation, although availability and cost issues often make this modality less practical in some locations. Patients with a higher risk of dural tears and subsequent cyst formation are those with a diastasis of 3 mm or greater and a young age. Ultrasound is also used to diagnose these tears. Normally, ultrasound waves do not penetrate an intact skull, but an opening (fracture) will allow the beam to pass through, and the practitioner can examine the integrity of the dura [61].

Injury to the neural tissue can vary in severity from a concussion, the mildest form, to a contusion or a diffuse axonal injury, producing severe, profound coma. A concussion produces a temporary disruption of cerebral function, generally lasting less than one day. The term MTBI is often used interchangeably with the term concussion.

Contusion injuries of the brain cause a more prolonged compromise of cerebral function than a concussion. On examination, the brain tissue is edematous and may have signs of localized hemorrhage. Loss of consciousness may occur for prolonged periods of time, and recovery outcomes may be unpredictable at the time of initial evaluation. Often, contusions occur as "coup-contrecoup" injuries. This injury emerges during rapid acceleration and deceleration of the head as occurs in a MVA. The "coup" injury occurs when the brain impacts the interior of the skull, leading to injury of the brain tissue at the site of impact. The "contrecoup" lesion can be of greater consequence; this lesion occurs on the brain at the side opposite from the initial impact. In other words, the brain is bouncing around inside the skull, causing damage to a number of areas in the brain. The greater the damage to the neural tissue, the greater the risk of severe brain injury.

Diffuse axonal injury is due to severe, sudden deceleration, often accompanied by rotational forces. This injury is described as a shearing injury; the axons within the white matter are torn, leading to disruption of the connections between the cortex and the lower brainstem. The coma that develops is profound and deep; some children remain in a persistent vegetative state following this type of injury.

Disruption of the cerebral vasculature produces a cerebral hematoma or hemorrhage. Accumulation of blood between the dura and arachnoid layers produces a subdural hematoma, the most common type of intracranial hemorrhage in children. Subdural hematomas are generally venous in origin and are classified in three categories: acute, subacute, and chronic. The child with an acute subdural will present with immediate alterations in cerebral functioning. A subacute subdural hematoma develops within two weeks of injury and is defined by a progressing decrease in level of consciousness during this time frame. A chronic subdural hematoma is commonly diagnosed months later when a child is evaluated for changes in personality, behavior, and/or cognition or an onset of seizures. The actual cranial insult may have been forgotten by the time of diagnosis.

An epidural hematoma occurs when blood accumulates between the skull and dura and is most commonly associated with a tear of the middle meningeal artery. This child may demonstrate rapid deterioration of mental status, possibly leading to profound coma. However, unique to children is an epidural hematoma that is caused by a venous bleed. These children may initially be asymptomatic. Neurologic deterioration occurs over time, thus compounding the diagnosis. An epidural bleed is easily diagnosed by head CT scan; the blood accumulation is said to be egg-shaped or lenticular.

Subarachnoid hemorrhage occurs when blood is deposited between the arachnoid and meningeal layers. Violent shaking of a child, such as in abusive treatment, can produce this type of intracranial hemorrhage. If a subarachnoid hemorrhage is suspected, a lumbar puncture will provide confirmation. However, lumbar punctures should be avoided in patients with epidural or subdural hematomas and should only be performed when these types of intracranial hemorrhages have been first ruled out and there is no evidence of increased ICP.

Intracerebral hemorrhage can occur at the direct site of impact where blood aggregates in the parenchymal tissue. The size of the hemorrhage directly influences the treatment and subsequent outcome of the child. A large hemorrhage will require surgical evacuation to prevent development of mass effect and herniation syndromes. Smaller lesions may be treated conservatively, as the excess blood will be resorbed over time.

Evaluation of the child with a suspected or confirmed traumatic injury to the head requires astute observation of the child's initial level of function and any subsequent changes in this level. As mentioned earlier, brain injuries are classified as mild (minor), moderate, or severe based upon the child's GCS score. The difficulty in utilizing the GCS score is that the method of scoring does not take into consideration children at varying levels of developmental maturation; thus the Modified Glasgow Coma Scale for Children has been developed (***Table 4***).

One of the major areas of concern in treating the child with a head injury is recognition of the extent of injury. A child who is diagnosed with a mild head injury may be sent home but the risk of delayed complications is always of concern. Identification of the extent of injury includes assessment of the child over a period of time, recognition of symptoms that have a high incidence of delayed complications, and the use of diagnostic evaluation tools such as CT scans and MRIs. Unfortunately, no purely clinical indicators, either alone or in combination, have been found to detect structural brain injury.

EVIDENCE-BASED PRACTICE RECOMMENDATION

According to the American College of Radiology, children 2 years of age and older who present with minor head injury (Glasgow Coma Scale score >13) without neurologic signs or high risk factors (e.g., altered mental status, clinical evidence of basilar skull fracture) do not require imaging studies. This recommendation excludes nonaccidental trauma.

(https://acsearch.acr.org/docs/3083021/Narrative. Last accessed December 8, 2020.)

Strength of Recommendation: 3 (Usually not appropriate)

Imaging recommendations have been developed to afford the healthcare provider with an organized strategy in determining when a child is a candidate for imaging studies. The liberal use of these studies can place undue burden upon the financial resources of the family and the healthcare system, while the underuse of these studies can lead to an increased risk of missed injuries, possibly leading to death or permanent disability in the child. One study demonstrated that 63% of scans in children with a GCS score of 13 or 14 were abnormal. These children had sustained injuries such as skull fractures, intracerebral hemorrhages, and cerebral contusions despite good neurologic function upon initial evaluation [63].

Children older than 2 years of age who present to the emergency department with a history of a mild head injury and who are neurologically normal and remain asymptomatic do not require imaging studies. If these children are symptomatic, with a

PEDIATRIC GLASGOW COMA SCALE			
Score	Responses by Age		
Eyes Opening			
	Patient >1 year of age		**Patient <1 year of age**
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, coos, or cries 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

Source: [62] *Table 4*

history of loss of consciousness, vomiting, headache, drowsiness, irritability, or post-traumatic amnesia, CT scanning should be considered [63]. If obtaining a scan is not practical, overnight hospitalization with astute assessment may be indicated. For the child with overt signs of neurologic compromise, CT scanning should be utilized to rule out underlying cranial injury.

Children younger than 2 years of age are more difficult to assess for a number of reasons. Verbal and motor skills may not be adequately developed to allow for accurate assessment and the sequelae of the head injury may vary. Infants may develop scalp hematomas in conjunction with a skull fracture. The liberal use of neuroimaging and skull radiographs is considered appropriate after injury in this age group [64; 65].

A child who is profoundly comatose is obviously one who has sustained major injury. However, MTBI is much more difficult to accurately assess. The CDC defines MTBI as "the occurrence of injury to the head arising from blunt trauma or acceleration or deceleration forces" [66]. One or more of the following conditions must also be present for diagnosis of MTBI [66]:

- Temporary confusion, disorientation, or impaired consciousness
- Loss of memory during the time immediately before, during, or after injury
- A period of unconsciousness lasting no longer than 30 minutes

These symptoms may be observed by others or self-reported by the patient. Patients may also present with the following neurologic signs [66]:

- Seizures occurring immediately after injury
- Irritability, lethargy, and vomiting following injury (especially in infants and young children)
- Headache, dizziness, irritability, fatigue, and poor concentration (especially in older children and adults)

If neuroimaging does not demonstrate evidence of underlying brain pathology, the child may be considered a candidate for discharge. Discharging the child to home is impacted by a number of issues, including medicolegal concerns and economic factors. Because the family must have access to proper care, distance and transportation to an appropriate facility must be investigated prior to discharging the child.

A child who is discharged after sustaining a MTBI must be cared for by an individual who will comply with recommended discharge instructions. The importance of frequent observation of the victim cannot be overlooked. Reiteration of the following instructions will enhance care provider compliance.

A child should be awakened every two hours. The child should be assessed for the ability to speak coherently and move his/her arms and legs. Pupils should be checked (the care provider should receive a demonstration on how to best check pupillary size and response). Any possible abnormal responses should be listed on the home care instructions, along with actions to take should these abnormal responses develop during the course of care. The care provider should notify the emergency department (or appropriate healthcare provider) if the child:

- Demonstrates excessive sleepiness
- Vomits more than twice
- Has unequal or abnormally shaped pupils
- Develops slurred speech
- Complains of a headache that worsens
- Demonstrates change in ambulation
- Develops seizures

If any of these signs are present, the child should be transported to the appropriate healthcare facility for further evaluation. The key to prevention of long-term sequelae is the early detection of patient deterioration.

Moderate and major traumatic brain injuries are those that produce a GCS score of less than 13. A GCS score of 9 to 12 is classified as a moderate injury.

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 multifactorial. 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. During transport, isotonic, glucose-free fluids should be given, although the amount and rate of administration remains an area of debate. Studies have shown that isolated hypotension in children can triple the mortality from pediatric brain injuries [67]. Couple the hypotensive episode with hypoxemia, and the mortality rate can quadruple [68].

Preventing hypoxemia means obtaining rapid control of the airway and supporting ventilation in the brain-injured child. Rapid sequence intubation should be utilized to obtain endotracheal tube placement as quickly as possible. All advanced life support personnel should be trained in rapid intubation techniques of children; the need for early intubation is standard in head injury resuscitation guidelines. With rapid airway control, children can arrive in the emergency department adequately ventilated, with improvement in their long-term outcomes. The exception is the child who has sustained concomitant chest trauma, such as a pneumothorax, which can lead to ongoing hypoxemic episodes.

Monitoring the child with a severe head injury can be challenging in many adult critical care units; thus, these children require transport to a specialized pediatric center with neurologic monitoring capabilities. Management strategies tend to aim at the management of cerebral perfusion pressure (CPP) rather than simply instituting therapies aimed at decreasing ICP. Mean arterial pressure (MAP) minus ICP equals CPP: CPP = MAP – ICP. Thus, preventing hypotension and maintaining an adequate MAP will help ensure adequate cerebral perfusion. Although ideal CCP has not been identified and varies based on the patient, a threshold of 40 mm Hg for patients 0 to 5 years of age and 50 mm Hg for patients 6 to 17 years of age has been suggested [69; 70].

Fluid management of the injured patient is aimed at preservation of blood volume and mean arterial pressure. Many advances in the methods of volume management have been studied in adult patients, but few studies have been instituted on pediatric neurotrauma patients [70]. In the adult patient, the use of hypertonic saline with accompanying control of osmolarity has been successful in controlling cerebral swelling. These strategies are currently being studied in children, and although controversy exists, many neurologists and neurosurgeons will recommend these measures for the management of intracranial hypertension in the severely brain-injured child.

EVIDENCE-BASED PRACTICE RECOMMENDATION

The Brain Trauma Foundation recommends that bolus hypertonic saline (3%) be given to pediatric patients with intracranial hypertension. Recommended effective doses for acute use range between 2 and 5 mL/kg over 10 to 20 minutes.

(https://www.braintrauma.org/uploads/10/11/guidelines_pediatric3.pdf. Last accessed December 8, 2020.)

Level of Evidence: II (Based on a moderate-quality body of evidence)

Other management strategies that are accepted include prevention of hyperthermia and hyperglycemia. Although in other parts of the world, including Europe, induced hypothermia is frequently instituted in trauma management, the U.S. studies of induced moderate hypothermia to control increased ICP have not found the technique to be beneficial [71; 72; 73]. Hyperglycemic episodes following brain injury have been found to reduce the incidence of positive outcomes; therefore, hyperglycemic fluids are avoided in the resuscitative and critical care phases of care.

One of the more common sequelae to brain injuries in children is the development of post-traumatic seizures. The incidence ranges from 1% to 6%; the more severe the injury, the greater the risk of seizure development. The injuries with the highest risk of seizure development are those that penetrate the dura, cause intracranial hemorrhage, or produce prolonged (>12 hours) unconsciousness [63].

Post-traumatic seizures are classified as early or late. Early seizures develop within the first 24 hours after injury and have the potential to exacerbate secondary injury. Late post-traumatic seizures occur a week or more after the traumatic episode. The prophylactic use of antiepileptics is not recommended in most patients. Those who may benefit from this prophylaxis are those with cranial penetration or hemorrhage. For children with mild head injuries and normal imaging studies, post-traumatic seizure management can be safely done on an outpatient basis and does not warrant hospitalization [70; 74].

EVIDENCE-BASED PRACTICE RECOMMENDATION

According to the American College of Radiology, children experiencing post-traumatic seizures should undergo MRI or CT scan of the head without contrast.

(https://acsearch.acr.org/docs/69441/Narrative. Last accessed December 8, 2020.)

Strength of Recommendation: 9 (Usually appropriate)

Advances in neurotrauma care include pharmacotherapy to control secondary injury, new monitoring modalities, and improved imaging techniques. Neuroprotective drug agents may prove to be useful. These drugs act on the neurochemical mediators of secondary injury, limiting long-term injury. Although improvement has been noted in some patients, global acceptance of these agents has yet to be achieved. Monitoring of patients is expanding beyond ICP monitors; both global and local sensors have demonstrated usefulness in providing information regarding patients' responses to therapies. Imaging techniques allow monitoring of the injured brain, blood flow, oxygenation, and metabolism, providing information on the exact location of compromise [52].

Management of brain injuries in children remains an area of intensive research and study. Resuscitation of the brain of the injured child involves achieving a balance between ICP reduction strategies and enhancing cerebral perfusion. Reduction of secondary injury should be utmost in the minds of all healthcare providers caring for the child with head injuries.

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. Maxillary fractures, also known as LeFort fractures, are classified as I, II, or III. A LeFort I fracture is a transverse fracture through the alveolar process and involves the nose and anterior teeth. A LeFort II fracture is a pyramidal fracture, including fractures of the midface, maxilla, and nose. With a LeFort II fracture, the nose and upper dental arch move as a unit. LeFort III fractures involve the orbits and are known as craniofacial separations. They are the most life-threatening of the three fracture types. All LeFort fractures can cause profuse bleeding, malocclusion of the teeth, and loss of the structural integrity of the oral cavity. Managing the airway of the child with a LeFort fracture in an emergency is often difficult, requiring intubation and, in extreme cases, needle cricothyrotomy.

A fracture of the mandible requires extreme force for the break to occur. Mandibular fractures are accompanied by multiple mucosal and gingival lacerations leading to a high risk of systemic infection. Maintenance of the airway with a bag-valve-mask device is impossible as the seal between the mask and the face is unattainable; thus, airway management presents a major challenge. Despite this dilemma, most children who can sit up, lean forward, and control secretions may be safely transported to the operating room without requiring airway intervention.

Fracture of the zygoma can occur in three places: the zygomatic arch, the infraorbital rim, and across the zygomatic suture. Often, the ocular muscles and nerve are trapped, leading to enophthalmos, diplopia, and possible visual loss. Ocular nerve damage requires immediate intervention. Surgical elevation of the depressed bone fragments can be done to relieve pressure on the neurovasculature.

The keys to management of maxillofacial trauma are airway management and hemorrhage control. Interventions to reduce infection and maintain a positive fluid balance are also critical. Associated injuries must be recognized. For example, blunt force to the head and face frequently causes simultaneous injury to the cervical spine.

Ocular trauma can affect the external eye socket, the eyeball, or both. Classification systems of ocular trauma have been developed to ensure that ocular trauma is consistently recognized and treated. One of the greatest challenges in the management of ocular trauma is the development of scar tissue, which inhibits regenerative capabilities. The conjunctiva, lens, and eyelid all regenerate well, but the optic nerve and retina have no regenerative capabilities.

The management options for optic nerve injury are few, and evidence of the effectiveness of interventions is weak. Management options that have been considered include steroid use, surgical decompression of the optic nerve, and close observation. Methylprednisolone was previously thought to be a potential treatment due to its recommendation in the treatment of acute spinal injury. However, that recommendation has since been disputed, and there is limited and insufficient evidence of clinical efficacy in ocular trauma. Surgical decompression of the optic nerve also has limited evidence and may actually cause damage to the optical nerve. Because of the relatively high rate of spontaneous recovery in traumatic optic neuropathy, the conservative measure of close observation is likely the safest method for management [46; 127; 129; 130].

The child with trauma to the head and face requires aggressive management to reduce mortality and long-term sequelae. Outcomes in the pediatric population are better than for adult patients; however, there are many children who survive with significant, life-changing sequelae following trauma to the head and face.

CASE STUDY

Patient A is 20 months of age and refuses to be restrained in a car seat. The family is late for a movie, and her mother does not want to deal with a temper tantrum. So, she decides to hold Patient A on her lap while her husband drives to the theater. While sitting at a stoplight, their car is hit head-on by a car being pursued by a police officer in a high-speed chase. Immediately prior to the moment of impact, Patient A's mother had let go of her daughter to put her hands up to protect herself from the impact. Upon impact, the child is thrown to the floor and rolls under the passenger side dashboard. The front end of the car is crushed accordion-style; the parents both strike the windshield and are unconscious.

Emergency medical service (EMS) responds to the scene and identifies only two victims, the parents. Utilization of rescue tool 10, also referred to as the "Jaws of Life," is required to extricate them from the vehicle. As the car is being pulled apart to remove the mother, Patient A's body rolls down from under the dash where she was trapped. It is only at this point that the EMS personnel are aware that they have a third victim.

The child is unconscious and unresponsive at the scene. She is transported to the local pediatric hospital, where she undergoes immediate resuscitation. Upon evaluation she is noted to have a depressed skull fracture over the right temporal area and a bulging fontanelle. An emergency CT scan is performed and demonstrates an epidural bleed, an intraventricular hemorrhage, and a subdural hematoma, along with the depressed skull fracture. She is admitted to the pediatric intensive care unit, where she remains profoundly comatose.

During the next two days, efforts at supporting the patient's neurologic status are performed, including optimizing her oxygenation status and ensuring adequate circulatory volume. She is on a ventilator and is paralyzed and sedated to ensure limited increases in ICP. Pharmacologic agents administered include mannitol, dexamethasone, and narcotics for sedation. Despite these efforts, no change in her condition is noted.

The mother does not survive the automobile crash, and the father remains comatose in the trauma intensive care unit at the trauma center 30 miles away. Patient A's extended family is notified of her poor prognosis, and studies of brain function are undertaken. She is pronounced brain dead and is disconnected from the ventilator. Prior to death, her family is approached regarding organ donation. As a consensus cannot be reached and her father remains comatose, no organs are procured after her death.

Case Study Discussion

Although devastating, Patient A's injuries are not uncommon. Parents who do not restrain children in appropriate car seats run the risk of these types of devastating injuries. The EMS personnel who arrived on the scene would have been able to find and treat her had she been in her car seat. However, because she was trapped under the dashboard, no resuscitation efforts were initiated for a long period of time. This delay in resuscitation may have contributed to her death, although the extent of her injuries was severe and survival may not have been possible even with significant, aggressive resuscitation.

The issue of organ donation was initiated with the family members. Whenever a trauma victim succumbs to injuries, organ donation should be a consideration. In this case, the child's parents were unable to participate in the decision regarding donation; therefore, organs were not procured. Many adults have become designated organ donors; however, such protocols do not exist for children. The belief is that the parent will always be available to make these decisions; however, as is evident in this case study, this is not always true. Discussing organ donation for both adults and children should be initiated within family units before such decisions are required.

TRAUMA TO THE SPINE AND SPINAL CORD

Although rare, accounting for approximately 5% of all cases of spinal trauma, pediatric spinal trauma is a devastating and life-threatening injury [126]. The long-term sequelae and physical requirements are phenomenal; throughout the lifespan of the injured child, the medical, emotional, and economic impact can be immense.

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 60% to 75% of injuries sustained involve the cervical portion of the neck [75; 126].

MVAs are by far the most common mechanism of injury to the spine in the pediatric population [76]. In addition to MVAs, children sustain injuries in acts of violence, falls, and sports-related activities [76].

Compression and contusion injuries are more common than transection of the cord. The point of maximum mobility of the cervical region progresses caudad 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 [75].

Age-dependent variables impact not only the level of injury but the type of injury as well. Small children have large heads and higher centers of gravity. In flexion injuries, the head will be the leading object, causing significant change in the shape of the vertebral column and cord. The muscles of the neck are underdeveloped, so flexion and extension injuries, such as "whiplash," are common. This flexibility of the spinal column means that children have a lesser number of fractures and a higher incidence of compression injuries when compared to adult patients. Regardless of this degree of movement, it is vital to remember that the cord is fixed both distally and anteriorly. The cord is anchored by the cauda equina at the termination of the cord and attached by the lumbar and brachial plexus at the anterior end. Thus, with movement, the cord will either be stretched or compressed.

Neck injuries involve more than the cord and vertebrae because the ligaments, the vasculature, and the airway may also be compromised. The most common finding upon physical examination in the child with a cervical spinal injury is midline cervical tenderness. Neurologic deficits may be present upon initial examination or may not develop until later in the course of care. Any child with a mechanism of injury suggestive of a spinal injury should be treated with full spinal precautions.

RAPID NEUROLOGIC ASSESSMENT OF SPINAL CORD INJURIES	
Assessment Parameter	**Level of Function**
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
Source: Compiled by Author	*Table 5*

Other symptoms may include muscle spasms, limitation of neck movement, and neurologic deficits. Paralyzed intercostal muscles may produce a "see-saw" respiratory pattern whereby the chest retracts and the abdomen distends with inspiration. This indicates that the sole muscle responsible for respiration is the diaphragm, and ventilatory support should be readily available if needed. The presence of other associated traumatic injuries should be determined, with head trauma being the most frequently occurring concurrent injury.

Testing neurologic function should begin as soon as possible after CAB support has been secured. Testing should include both pinprick and light touch, as these sensations are carried in different tracts of the cord (the anterior portion of the cord carries the pain fibers, while light touch is carried in the posterior columns). The level of function may be rapidly assessed utilizing the chart in ***Table 5***. It is essential to remember that C4 innervation is necessary for respiration; patients with injury to C4 or above will most likely require ventilatory support. However, healthcare providers must remember that cord edema can progress both proximally and distally, and it is important to assess ventilatory effort in any child with a cervical injury regardless of its location.

Many children suffer contusion and compression injuries, as mentioned. This type of damage may lead to an incomplete injury, producing an identifiable pattern of function. Anterior cord syndrome most commonly occurs secondary to hyperflexion of the neck. This produces a pattern of complete motor paralysis below the level of injury. Additionally, pain sensation is lost, but light touch remains intact. Central cord syndrome is common with a compression injury and produces a muscle weakness or paralysis that affects the upper extremities to a much greater degree than the lower extremities. Brown-Sequard syndrome (also known as half-cord syndrome) occurs when half of the cord is injured, producing paralysis and loss of proprioception and touch on the same side as the cord damage, while loss of pain and temperature occurs on the side opposite of the cord lesion [77]. These cord syndromes may or may not be reversible dependent upon the extent of damage and the subsequent degree of post-injury edema.

SCIWORA is a pattern of trauma that is unique to the pediatric population. The traumatized child will present to the emergency department with transient neurologic and/or motor deficits; however, radiologic examination demonstrates a normal spinal column. SCIWORA develops in children because the vertebral column is able to stretch up to 2 inches, while the cord can only elongate one-quarter of an inch without causing cord disruption [75]. If the vertebral column is stretched within its limits, but beyond the limits of the cord, the cord will be compromised, producing neurologic symptoms despite the normal cervical spine x-ray.

The physical findings of SCIWORA cannot be ignored even though a cervical spine film is normal. Unfortunately, many patients with SCIWORA have a complete injury and lifelong disability, and some patients may have a delayed onset of neurologic deficits [75]. Patients may complain of or demonstrate transient symptoms immediately after the injury, including paresthesia of the legs and hands, generalized weakness, and/or a lightning (burning) sensation down the spine associated with neck movement. The delay in onset of symptoms ranges from 30 minutes to four days [78]. In many instances, the child may have been discharged to home and experience these deficits either at home or school, away from medical care. Additionally, there appears to be a risk of developing a second, more severe spinal cord injury, often due to trivial trauma, between 1 to 10 weeks after the initial injury [78].

Although the focus of most pediatric trauma education is directed at recognition and treatment of cervical spine injuries, it must be remembered that injuries occur at all levels of the spinal column. In small children, the most lethal injury occurs at C2 and is known as a hangman's fracture. The neck is hyperextended and the cord disrupted, leading to immediate loss of ventilatory drive and subsequent death. Trauma between C3 and C7 is difficult to diagnose as most of these injuries are ligamentous in nature. Patients with a C7 fracture commonly have an associated upper rib fracture.

Thoracic spine injuries are most commonly compression type injuries, often sustained in falls. The thoracic spine has strong disks and end plates and obtains supplemental support from the rib cage. Compression injuries have relatively good outcomes when treated with symptomatic support and rest.

Fractures occurring in the thoracolumbar region are commonly burst injuries. A Chance fracture occurs when a lap-belt-only type of restraint is utilized. In a high-speed deceleration, the child flexes over the restraint device, stretching and displacing the vertebral column. These injuries are often accompanied by internal abdominal injuries, producing the pattern of injury known as lap belt complex.

Lumbar fractures may also be caused by lap belt use. Frequently, the disk is injured and may protrude between L3 and L5. Unstable fractures are frequently repaired surgically; the resultant kyphosis that may occur can lead to loss of stature as the child matures.

Diagnosis of spinal injury includes positive findings during physical assessment, radiologic evidence, and a high index of suspicion. A single lateral cervical x-ray is not adequate in many instances; however, three views (cross-table lateral, anteroposterior, and odontoid views) will improve the sensitivity of this diagnostic tool. The series must include all seven cervical vertebrae to allow for full evaluation.

While x-rays remain the standard for rapid evaluation and gross screening of injury, MRI provides the practitioner with the most definitive information. MRIs allow for screening of soft tissue injuries, including edema and hematomas, and are considered the diagnostic method of choice for determination of cord injury [79].

EVIDENCE-BASED PRACTICE RECOMMENDATION

The American Association of Neurological Surgeons does not recommend cervical spine imaging in children who are older than 3 years of age who have experienced trauma and who are alert, have no neurologic deficit, have no midline cervical tenderness, have no painful distracting injury, do not have unexplained hypotension, and are not intoxicated.

(https://www.cns.org/guidelines/browse-guidelines-detail/18-management-of-pediatric-cervical-spine-spinal-c. Last accessed December 8, 2020.)

Strength of Recommendation: II (Reflects moderate clinical certainty)

Confounding radiologic diagnosis is the difference in anatomic development of children at various ages. Up to 46% of children younger than 8 years of age may demonstrate a pseudosubluxation of C2 on C3. Growth plate lines that are fusing may be interpreted as fractures. Lordosis, which is present in adult radiographs, may be normally absent in children up to 16 years of age [78]. In unclear cases, a radiologist specializing in reading pediatric spinal films should be consulted.

Immediate management of the child suspected of sustaining spinal trauma includes instituting full spinal precautions, securing the child to a backboard, and stabilizing the neck to prevent flexion, extension, and rotation. Hard cervical collars may not be available in the appropriate size, and utilizing a poor fitting collar may cause more harm than good. If an appropriate collar is not available, the neck may be stabilized with towels, blankets, IV bags, or even the child's shoes. It is important to assess the child once secured to the backboard. The large occiput of the head may normally push the head forward when resting on a hard surface. The child should be further stabilized to achieve neutral alignment. This can be achieved by placing a small towel roll between the child's shoulder blades, establishing alignment. The goal of alignment is that the external auditory meatus is in line with the shoulder in the coronal plane. An additional method of stabilization in the child weighing less than 40 pounds is to leave the child in his or her car seat. Towels and blankets may be secured about the head of the child to prevent movement.

Immediate evaluation of the airway, breathing, and circulatory status of the child must be undertaken, remembering that the increased incidence of high cervical injuries in small children predisposes them to lose their ventilatory drive. If required, intubation should be performed with minimal neck movement. Only practitioners with an appropriate level of experience should attempt intubation in this patient.

Evaluation of concurrent injuries must be a priority. A child may survive the spinal insult but may not survive the subsequent massive intracranial bleed. Recognition of other injuries should be systematically evaluated utilizing the head-to-toe approach, as recommended in trauma life support courses. Documentation of the level and type of neurologic findings should be instituted early and repeated on a frequent, regular basis. It is important to remember that the child may have a fracture at one level and disk injury at another level. Improvement or deterioration of the patient's condition will be quickly recognized utilizing this systematic approach.

The role of steroids after acute spinal injury is unclear. In 1990, the National Acute Spinal Cord Injury Study (NASCIS II) documented the benefits of early steroid utilization and indicated that a dosage regimen of 30 mg/kg IV bolus of methylprednisolone within 8 hours of injury, followed by a drip at 5.4 mg/kg per hour for the subsequent 23 hours (and up to 48 hours total) significantly improved motor neurologic and functional status outcomes in patients with acute spinal cord injury [80; 81]. Although off-label, this was a standard in treatment until 2013, when the Congress of Neurological Surgeons found insufficient evidence of clinical efficacy and recommended against the routine use of methylprednisolone in the treatment of acute spinal cord [46; 127]. Other studies have also recommended against this practice, including a meta-analysis of clinical studies published in 2019 that indicates that the use of methylprednisolone for acute spinal injury does not contribute to better neurologic recoveries but increases the risk of gastrointestinal hemorrhage and respiratory tract infection [128]. While practice has moved away from the routine use of methylprednisolone for acute spinal injury, controversy remains and more research is required to obtain a definitive recommendation.

Management of the child depends upon age, severity of injury, and the degree of neurologic compromise. Children with unstable fractures or those with worsening neurologic deficits are surgically managed. For those children not surgically stabilized, halo stabilization should be a part of treatment [75]. Children with cord injuries have more favorable outcomes after injury as compared to adult trauma patients.

Healthcare providers must also address the emotional impact of these injuries. The potential loss of bodily function is devastating, and patients may deny the consequences of such injuries. Additionally, pediatric patients may sustain injury pursuant to a risky behavior that they may have been instructed not to participate in. The guilt and anger that arise in these patients is incredible, and early psychosocial counseling may favorably impact their long-term outcomes.

The future of spinal cord trauma management is promising. Surgical techniques, including fusion and posterior instrumentation, utilized in adult spinal patients are being successfully implemented in children [75]. It is possible that the spinal cord has the ability to regenerate; however, these regenerative properties are somehow compromised after injury. Stem cell research may provide some answers to the problem. Work at unlocking the keys to these mysteries is paramount in reversing the devastating consequences of spinal cord trauma.

Spinal cord injury is a catastrophic injury. As changes in spinal cord management continue to develop, children will live longer, more productive lives after injury. Prevention of these injuries should continue to be a priority. Only with the reduction in the number of injuries can we be successful at reducing the tremendous costs, both monetary and physiopsychologic.

CASE STUDY

Patient B is a boy, 14 years of age, attending a birthday party at the local community pool. He is an excellent swimmer and has always been safe around pools. When he is swimming in the pool, another guest runs and jumps into the pool, landing on top of Patient B. The force of the impact is directed at his head and neck. Immediately, he sinks to the bottom of the pool and is rescued by the pool lifeguard. After being brought to the surface, mouth-to-mouth resuscitation is initiated. Within moments, Patient B chokes and starts to breathe on his own. However, he is unable to move his extremities and feels no sensation below his shoulders.

EMS personnel arrive on the scene, and Patient B is placed on a backboard and put in full spinal precautions prior to being removed from the water. He continues to breathe on his own after the initial period of apnea. He is transported to the local emergency department for evaluation.

Upon arrival at the emergency department, the patient continues to demonstrate flaccid paralysis of both his upper and lower extremities. Neurologic assessments are initiated and continued on an every 15-minute basis. Cervical spinal x-rays show a fracture between C5 and C6. A CT scan demonstrates diffuse swelling in this area, with severe injury to the spinal cord. Supplemental oxygen is provided, a Foley catheter is placed, and the neurosurgeon on call is notified.

Subsequently, Patient B is taken to the operating room for stabilization of his cervical spine. He is placed in traction in the operating room and transferred to the intensive care unit. During his stay in the intensive care unit, neurologic assessments are continued although no change is identified. During this time, psychologic counseling is initiated, as it is felt that the injury sustained will be permanent, rendering the patient quadriplegic.

Initially, Patient B's frame of mind is good; he feels that he can overcome his injury and be able to walk again. Despite counseling to the contrary, he continues to insist that he is going to get better. Within two weeks, he is ready to transfer to a spinal cord rehabilitation center. It is at this point that he realizes the full extent of his injury and becomes profoundly depressed. At times he expresses suicidal ideology and receives intensive counseling. During the next three months, Patient B and his family learn to deal with his healthcare requirements. He is discharged to home with around-the-clock nursing care.

Case Study Discussion

Despite the fact that most spinal cord injuries occurring in swimming pools follow diving accidents, other mechanisms of injury can be the cause. In this case, the victim was within the bounds of safe swimming and was still injured due to another child's inattention to safety. Patient B was immediately given mouth-to-mouth resuscitation. Due to this prompt response, near-drowning was not a complication of this injury.

The appropriate stabilization and resuscitation measures were undertaken without improvement in his condition, and the x-ray and CT scan demonstrated significant injury. The extent of injury and long-term effects may not be easily identified at the time of injury, but the patient should be given the benefit of the doubt when considering treatment options.

The depression that Patient B demonstrated is common in all patients suffering permanent spinal cord damage. Compounding this fact is that he is 14 years of age and has his entire life ahead of him. Adolescent depression is becoming increasingly common as children face new challenges. Teenage boys have high rates of suicide, and Patient B required intensive counseling to work through the depression he developed.

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. These injuries are generally managed nonoperatively unless accompanied by significant, persistent hemorrhage.

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. The child may be discharged to home if none of these signs of trauma are present. The primary care provider must be informed of these developing signs, and the child should return to the emergency department if his or her condition deteriorates.

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. The most important intervention to prevent respiratory failure is aggressive pulmonary toilet to improve oxygenation. Unresolved contusions can lead to pneumonia and atelectasis if untreated.

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. Definitive diagnosis is by chest x-ray. For pneumothoraces of greater than 20%, or those that cause significant respiratory distress, the intervention of choice is chest tube placement with water seal drainage until the lung re-expands.

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. However, this is a temporizing measure, and definitive treatment requires placement of a chest tube to water seal drainage. 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. There is a risk in these cases when a chest tube is placed for drainage. This low pressure system is altered and the bleeding may start up again, leading to further blood loss and risk of cardiovascular collapse. Whenever a chest tube is inserted for drainage, the practitioner caring for the patient must monitor the blood loss and look for signs of deterioration immediately after chest tube placement.

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 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. Measures of pain control include intercostal blocks and thoracic epidural analgesia with continuous infusions of narcotics and local anesthetics.

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.

Management of tamponade requires two steps. Initially, the cardiovascular system must be supported to ensure adequate cardiac output, and secondly, the cause of bleeding must be identified and controlled to prevent further blood accumulation. When the child presents to the emergency department with a low blood pressure and tachycardia, the initial resuscitative effort is to begin fluid resuscitation for volume support. In the child with cardiac tamponade, this additional fluid may actually worsen the child's condition if an increased volume of fluid leaks into the pericardial sac. If this develops, cardiac tamponade is suspected and fluids are slowed or discontinued until the source of bleeding can be identified and managed.

Removal of blood from the pericardial sac requires insertion of a needle into the sac and the aspiration of blood (pericardiocentesis). The child should demonstrate immediate improvement, as the heart is able to improve its pumping capabilities. Once the blood has been removed by pericardiocentesis, the child must be monitored for recurrence of blood accumulation. Until the source of bleeding is controlled, the risk of recurrence is high. Once resolved, the sequelae are minimal and long-term outcomes are normal.

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 [82]. 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 [82]. 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 [83].

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 [84]. Additional measures to reduce death include the development of safer equipment.

In 1996, the Consumer Product Safety Commission recommended the use of soft baseballs. However, it has been found that softer, heavier baseballs, also referred to as reduction-in-force baseballs, do not reduce impact [83; 84]. Lighter mass baseballs have been determined to be safer, especially when used in conjunction with effective chest protectors.

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 intra-abdominal 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 parenchyma. Other signs that may occur are evidence of pneumothorax, bowel sounds in the chest, and a nasogastric tube in the chest as seen on chest x-ray (although chest x-rays are only diagnostic 25% to 50% of the time). Repair of the diaphragm should be undertaken. While awaiting surgery, the child's respiratory status should be maximized to limit the developing hypoxemia.

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 three to four 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 should be remembered that 12% of patients will have a concurrent cervical injury and should be treated with cervical spinal precautions. Although 85% of the injuries can be managed conservatively or with a chest tube, the goal of management is ventilatory support and improvement in the oxygenation status of the child. Without adequate pain control, these measures will be more difficult to attain; pain control should be instituted early and continued throughout the course of care.

CASE STUDY

Patient C is a boy, 8 years of age, who is riding his bike when hit by a car. He is knocked to the ground and a subsequent car, which was unable to stop in time, runs over his chest wall. His t-shirt shows tire marks across his anterior chest. However, immediately following being run over, he jumps up and starts yelling at the driver, who also damaged his new bicycle. Witnesses call 911, and emergency medical care personnel arrive within minutes of the accident. Upon arrival, Patient C is walking around, expressing concern regarding his new bike. He demonstrates no signs of injury other than the tire marks across his chest. Because of the mechanism of injury, the EMS personnel insist that he be transported to the local emergency department for assessment and treatment, if necessary.

Upon arrival in the emergency department, his vital signs are stable, his oxygen saturation is 96%, and a chest x-ray is normal. His parents are called, and the patient is to be discharged to home. Prior to leaving, his parents are instructed to return to the emergency department if any signs of developing respiratory distress are evident.

Case Study Discussion

Most children who are run over by an automobile will sustain multiple injuries; however, in this case, Patient C sustained no identifiable trauma immediately following the accident. As is common in children, his chest wall was very pliable, and the weight of the car crushed his chest wall without producing injury to the bony segments. The risk in this type of trauma is that underlying pulmonary injury may develop, leading to significant respiratory distress. Upon admission to the emergency department, no respiratory distress was evident, his vital signs were stable, and his oxygen saturations were within normal limits. The most common delayed development in this case would be developing respiratory distress secondary to a pulmonary contusion. Prior to his discharge, the parents were instructed in identifying signs of respiratory distress and the requirement to return to the emergency department should these signs develop.

In this case, Patient C did very well and never required follow-up care. As for his t-shirt, he never washed it, and he keeps it on his wall as a reminder of the day he was run over by a car and walked away.

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. The focus of trauma care has changed from immediate surgical intervention to a nonoperative, wait-and-see approach in children with solid organ 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 [38].

The second most common cause of abdominal trauma in children is pedestrian injury [38]. 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 intra-abdominal 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 handlebar-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 [38].

EVIDENCE-BASED PRACTICE RECOMMENDATION

The American Urological Association recommends surgeons should perform scrotal exploration and debridement with tunical closure (when possible) or orchiectomy (when non-salvageable) in patients with suspected testicular rupture.

(https://pubmed.ncbi.nlm.nih.gov/24857651. Last accessed December 8, 2020.)

Level of Evidence: B (Randomized controlled trials with some weaknesses of procedure or generalizability or generally strong observational studies with consistent findings)

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 [38]. Evaluation of penetrating trauma is slightly different than for blunt injuries and will be discussed subsequently.

Assessment of abdominal trauma in children can be difficult. Preverbal children will not be able to accurately identify the location and extent of pain, while older children may guard their abdomen during assessment to reduce the risk of further pain. Furthermore, administration of pain medications can alter the exam. Therefore, most surgeons prefer that the child have a full abdominal workup prior to receiving pain medications. Obtaining diagnostic studies will assist care providers in recognizing the presence and extent of injury in many children.

CT scans are the diagnostic modality of choice in stable patients who have sustained blunt abdominal trauma [38]. With the increasing availability of CT scanners, the incidence of exploratory laparotomies has decreased significantly. CT scans allow for identification of many injuries, as well as grading the severity of injury. This information is utilized in making choices on how to best manage the patient. The disadvantage of CT scans is the decreased sensitivity and specificity in recognizing trauma to the pancreas, bowel, bladder, and mesentery. Utilization of contrast material, both orally and intravenously, can improve the diagnostic capabilities in some patients; however, the risk of aspiration following oral contrast administration is of concern. Patients sustaining penetrating trauma may benefit from a quick abdominal x-ray, allowing for identification of free air or foreign bodies.

In unstable patients, ultrasonography is utilized as a screening tool. It is fast, noninvasive, inexpensive, and interpreting ultrasound results has proven to be readily learned. Ultrasound assessment is performed utilizing the focused assessment with sonography for trauma (FAST) technique, which is useful in deciding who would benefit from laparotomy [85].

While this method of evaluation is common in adult abdominal trauma, its use is still being studied in pediatric patients with abdominal injuries [86; 131]. The approval and introduction of specific ultrasonography contrast agents for contrast-enhanced ultrasound has enabled a better identification of traumatic organ injuries in the pediatric population [87; 88]. One study found contrast-enhanced ultrasound to be more sensitive and accurate than baseline ultrasonography and nearly as sensitive as CT scan [89]. MRI has also been used to visualize soft tissue abdominal trauma.

Diagnostic peritoneal lavage (DPL) may be performed in children; however, due to the limited size of the abdominal cavity, the risk of complications is higher. With the advent of ultrasonography and CT scanning, DPL use is rapidly declining. However, in a rural setting without readily available CT scanning, DPL may be a useful diagnostic tool, allowing for recognition of free blood within the abdominal cavity. The risks of DPL in children include bowel perforation, injury to the solid organs, and vascular injury.

Laboratory evaluation of abdominal trauma may or may not be useful in the immediate situation. Changes in body chemistry are not always immediate; thus, laboratory values may be within normal limits during the initial admission screening. Following the changes in hematocrit and hemoglobin over time provides a good indication of ongoing blood loss. Obtaining a baseline hematocrit and hemoglobin upon admission may be useful for later comparison. Liver function tests (LFTs) are altered with hepatic trauma. Although the values obtained may not clarify the extent of injury, LFTs may be useful in diagnosing liver injury when CT scanning is not immediately available [38].

Diagnosis of pancreatic injury is challenging, as elevated amylase and lipase levels are common following many types of abdominal injury. Although the extent of elevation may be questionable, it is recommended that children with suspected injury to the pancreas have amylase levels measured initially and repeated as needed. The only other laboratory test that is useful during initial evaluation is a urinalysis, which demonstrates either gross or microscopic hematuria as an indicator of renal trauma.

Evaluation of penetrating trauma requires additional studies. The primary concern with these injuries is the depth of injury and potential penetration of the peritoneum. Laparoscopy has been shown to be a useful method of diagnosis as well as surgical repair [90]. Liver, spleen, and diaphragmatic tears may be sutured and repaired utilizing this method, preventing exploratory laparotomy. One retrospective review examined more than 16,000 pediatric trauma admissions that required surgical abdominal exploration. The authors found that laparoscopy reliably resolved diagnostic uncertainty in select cases. Furthermore, in a hemodynamically stable patient with a concerning exam and inconclusive imaging, laparoscopy provided sensitive diagnostic capability and opportunity for definitive repair with diminished surgical morbidity [91].

The spleen is the most commonly injured solid organ in abdominal trauma in children. Splenic injuries are graded on a scale of I to V. All children with a grade V injury undergo splenectomy [92]. 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. Falling hematocrit and hemoglobin levels may indicate ongoing blood loss.

Nonoperative management of splenic injuries in children has been utilized for a number of years. The impetus for this change is that post-splenectomy sepsis carries a high mortality rate in this age group. The controversy regarding nonoperative care is how to best manage the patient during the first few days post-injury. Some practitioners advocate three to five days of bed rest, but most studies have found that bed rest does not improve success rates [92; 93]. While there is consensus that the child should be kept quiet, constant monitoring in an intensive care unit may not be necessary for most children. Following the hematocrit levels in children will help to recognize potential problems. If the hematocrit level falls, a repeat CT scan is generally obtained.

A common splenic injury is a hematoma. The thick capsule surrounding the spleen limits bleeding and protects the spleen from actual tissue disruption. The recommended treatment is nonoperative management; repeat CT scans or ultrasound should be obtained post-injury [94]. If contact sports were to be initiated prior to complete resolution, the risk of spontaneous rupture is high with an increased risk of hemorrhage and death. Nuclear medicine liver/spleen scans can also be used to follow these patients.

The incidence of post-splenectomy sepsis has decreased over the years. The liberal use of antibiotics and the pneumococcal vaccine have significantly controlled complications. Asplenic individuals are more at-risk for postoperative pneumonia, infection, abscess, and coagulopathies rather than post-splenectomy sepsis. Other sequelae to splenic injury include subphrenic abscess, pancreatitis formation, and embolic events when clots form secondary to the rebound elevation of thrombocytes.

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. Liver injuries are similarly graded on a scale of I to V, with V being the most life-threatening injury associated with massive hemorrhage. The symptoms of liver injury include right upper quadrant pain and tenderness. Increasing abdominal girth in children may be an indicator of increasing intra-abdominal volume. Persistent hypovolemia in spite of adequate volume replacement may indicate massive hemorrhage.

If the child is stable, the trend in hepatic trauma management is to monitor the child and treat the injury nonoperatively. Patient selection for nonoperative management is based primarily upon the hemodynamic stability of the patient, not the grade of injury. The impetus for nonoperative management is the fact that patients who are treated without surgery have a lower mortality rate, require fewer transfusions, and have less risk of post-operative infection [95].

Delayed bleeding is rare after liver injury. Following the hematocrit and hemoglobin levels will allow for identification of ongoing blood loss. For those patients with continued bleeding, arterial embolization to control bleeding has met with success. This method of stabilization prevents the surgical stress associated with exploratory laparotomy.

Renal injuries are also graded I to V. Renal injuries in children are also treated nonoperatively, especially grade I or II injuries. Surgery is recommended for any child sustaining vascular injury, with the goal of surgery being salvation of the organ rather than removal. Hematuria, either gross or microscopic, is an indicator of renal trauma. Grey-Turner sign, a bruising over the umbilicus and the flank area, is rapid to develop in children with vascular hemorrhage. Associated GU injuries include trauma to the ureters, urethra, and bladder.

Bladder rupture is recognized by gross hematuria and lower abdominal pain. In infants and young children, the bladder is an intra-abdominal organ and signs of injury may not be initially evident. Other signs of rupture include an inability to void, little or no urine output after Foley catheter placement, and possibly an associated pelvic fracture. Bladder repair is undertaken with intraperitoneal ruptures and large extraperitoneal ruptures. Other small injuries can be treated with suprapubic drainage [96]. Delayed complications of renal trauma include hypertension and infection.

EVIDENCE-BASED PRACTICE RECOMMENDATION

According to the American College of Radiology, hematuria is frequently found in the pediatric patient with blunt abdominal trauma. Macroscopic (gross) hematuria is a finding that necessitates a radiologic evaluation of the abdomen and pelvis.

(https://acsearch.acr.org/docs/69440/Narrative. Last accessed December 8, 2020.)

Level of Evidence: Analysis of the current literature and expert panel consensus

Bowel injuries in children are common with lap belt complex. Rupture of the bowel leads to spillage of bowel contents into the peritoneal cavity. The omentum is not well developed in children; thus, free flowing contents spread easily throughout the peritoneum, leading to significant peritonitis. The jejunum is the most commonly injured segment of the bowel. Signs and symptoms of injury may be delayed up to 12 to 18 hours [96]. Difficulty in diagnosis is complicated by the lack of external signs of trauma. Fifty-five percent of injuries caused by seatbelt compression have no evidence of external ecchymosis. Developing signs of bowel injury include peritonitis, elevated temperature, tachycardia, and diminished urine output. Hematomas of the bowel may cause symptoms of obstruction, including pain, vomiting, and distention.

As noted, pancreatic injuries are difficult to diagnose. The pancreas is located in the retroperitoneal space, so abdominal findings may not be present. Depending upon the extent of injury, simple nasogastric drainage and bowel rest may be adequate in the nonoperative management of these injuries. Those injuries in which the pancreas is transected require surgical repair. Pancreatic pseudocysts are common in the first three to seven days post-injury, and large, symptomatic cysts may require percutaneous drainage. Other sequelae include the development of hypocalcemia, acidosis, and abscess or fistula formation.

Penetrating trauma requires a different approach to management. Injuries that penetrate the peritoneum require surgical closure of this cavity. In unstable patients, the use of damage control surgery, or abbreviated laparotomy, should be considered. Often, the patient has other multi-system trauma, such as concomitant head or chest injuries, that preclude long operative times. Damage control surgery is a step-wise approach to repair. The initial operation is of short duration, with the goals of surgery to control hemorrhage and prevent further contamination leak. The patient is then transferred to the surgical intensive care unit for further resuscitation and stabilization. A planned reoperation is scheduled for 24 to 48 hours after injury to perform definitive repair. This method of repair has two distinct advantages: the patient is not subjected to a lengthy and often life-threatening initial surgery, and the bowel edema that develops postoperatively is allowed to resolve prior to definitive repair [97]. The laparoscope has been used with increasing frequency to diagnose and even repair intra-abdominal injuries. When it is used successfully, it results in fewer postoperative sequelae and shorter hospital stays [93; 98; 99].

Another complication possible following abdominal injury is the development of abdominal compartment syndrome [100]. Bowel edema and fluid sequestration increase the volume of the intra-abdominal cavity, which in turn increases pressure within this cavity. As the intra-abdominal pressure rises, there is an associated drop in venous return to the heart and subsequent decrease in cardiac output. The patient then experiences hemodynamic compromise.

Normal intra-abdominal pressure ranges from 0–15 mm Hg. Intra-abdominal hypertension is defined as an intra-abdominal pressure greater than 15–20 mm Hg. As the pressure increases, the abdomen becomes tensely distended and oliguria may develop. The systemic effects include compromise of the cardiac, respiratory, and renal systems, leading to systemic collapse. Intra-abdominal pressure can be measured using grades I to IV. A pressure of 30 mm Hg may signal the development of organ cardiovascular collapse [101].

Management of abdominal compartment syndrome includes recognition and prevention with alternative surgical closure methods [102]. With high intra-abdominal pressures, surgical decompression may be required to prevent death of the patient. In the operating room, decompression is preceded with volume resuscitation, as opening the abdomen can cause a sudden shift of volume, leading to vascular collapse. When the abdominal edema and fluid shifts have stabilized, the abdomen may be closed again with minimal risk of a recurrence. Volume-controlled percutaneous catheter drainage has been found to be a minimally invasive and safe decompression method [103].

Advances in the care of the child with abdominal trauma include early enteral feeding, new generation antibiotics, and new closure techniques. Early enteral feeding has demonstrated a decrease in post-injury sepsis and multi-organ failure. As soon as the ileus resolves, tube feedings are initiated and villus function in the bowel is promoted. The use of antibiotics has also decreased the risk of post-operative infection, primarily the development of peritonitis.

With the development of new interventions and a reduction in operative procedures, the future of the management of abdominal trauma in children will continue to evolve. Deciding how and for what length of time a child who is treated nonoperatively should be kept quiet will be an area of intensive study over the next few years. The economic impact of keeping children hospitalized unnecessarily will be analyzed, with the early return to a pre-injury way of life being the primary goal of care.

CASE STUDY

Patient D is a girl, 7 years of age, who is riding in the center backseat of her automobile restrained by a lap belt. The car is in a high-speed crash, causing the patient to be thrown forward over the top of the lap belt. The lap belt keeps her in her seat, but her body is flexed over the belt, and her forehead impacts the back of the front seat.

Immediately after the crash, she is screaming and crying. She is extremely upset by the crash, and it is difficult to assess if she is merely upset or if she is indeed injured. Because of the mechanism of injury, she is placed on a backboard in full spinal precautions and transported to the nearest trauma center. Upon arrival in the emergency department, a report is given as to the type and mechanism of injury. She has quieted down by this time and is only shaking her head yes or no when questioned about her injuries. As part of the head-to-toe assessment, the nurse begins palpating her lower abdomen, which causes Patient D to scream and begin crying. Further assessment of her abdomen is deferred, as she is crying uncontrollably at this time and information is difficult to ascertain.

The head-to-toe assessment demonstrates a bump on the patient's forehead, ecchymosis over her abdomen below her umbilicus, and a bruising over her right flank. Due to the mechanism of injury, it is suspected that she has sustained abdominal trauma, possibly a ruptured bowel secondary to seatbelt compression. X-rays and lab results are obtained and all are within normal limits. Eventually, Patient D quiets down, and she is transferred to the pediatric intensive care unit for further stabilization.

During the first few hours in the pediatric intensive care unit, she remains quiet and relatively pain free. The ecchymosis over her flank area increases in size, and her urine output falls to less than 1 cc/kg/hr. A urinalysis is obtained and demonstrates microscopic hematuria. Renal trauma is suspected; however, the decision is made to treat it nonoperatively and continue to monitor the patient in the intensive care unit. Her fluid intake is increased slightly in an effort to prevent acute tubular necrosis from developing.

During the middle of the night shift, she sustains a respiratory arrest. All efforts at resuscitation are performed without success. Patient D is pronounced dead 45 minutes after the onset of resuscitative efforts.

Case Study Discussion

This case study demonstrates the type of injuries that can be sustained when children are restrained with only a simple lap belt. There is tremendous effort underway to notify parents of the dangers of lap belts and the benefits of booster seats for children younger than 8 years of age. Had this type of restraint been utilized, the injuries to Patient D may have been minimal, if occurring at all.

A number of omissions were made in her assessment and resuscitation. The bruising over the flank area is a hallmark sign of renal trauma in children, and this should have been suspected much earlier in her course of care. The assumption that she sustained seatbelt-induced injuries was correct; however, it focused the care provider's attention on her abdomen when other injuries may have been present.

Another injury that may occur secondary to seatbelt injury is injury to the lumbar spine. No studies were performed to rule out this injury.

On autopsy, the cause of her respiratory arrest was determined to be secondary to a large subdural hematoma that was not identified during her care. Because the patient was verbal and crying, it was assumed that she was neurologically intact. Her quiet behavior may have been an indication of neurologic deterioration rather than that she was just "being a good girl." The bump on her forehead that was identified in the emergency department should have alerted her care providers to the risk of neurologic injury, and further studies should have been performed.

Because Patient D did not survive, the extent of her injuries will never be known. What is known is that injuries were missed, and this played a direct role in her death. This case illustrates the horrible outcome that can occur when trauma care providers focus on one specific body system that is injured and overlook other less obvious, yet life-threatening, concurrent injuries.

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. Children also respond better to treatment, with post-casting joint stiffness and muscle atrophy being minimal.

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 practitioner from missing undetected injuries.

Accurate assessment of orthopedic trauma can be hampered when a child is in pain. Pain control measures should be instituted early and repeated on an as needed basis. An evaluation of neurovascular function is critical in order to help ensure viability of the injured area. The five Ps of assessment provide a useful mnemonic device for assessment. The patient should be assessed for:

- Pain
- Pallor
- Pulselessness
- Paresthesia
- 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. If a practitioner were to start at the point of pain, further assessment would be hampered, as the child would protect the injured area from further poking and prodding. Occasionally, assessment of the injured area may present an unclear picture; assessing the structures on the uninjured side often allows for appraisal of the nuances of the child's skeletal system.

Musculoskeletal trauma may present in many forms: fractures, dislocations, soft tissue injuries, or a combination of one or more of these injuries. The vast majority of orthopedic trauma sustained by children can be treated in the emergency department with follow-up orthopedic evaluation within 24 to 48 hours. Injuries that are limb- or life-threatening require immediate evaluation and stabilization to prevent untoward complications, including death and disability.

As in adults, pediatric fractures are either open (compound) or closed. The child must be evaluated for other forms of life-threatening trauma, including trauma to the head, neck, chest, and abdomen. Once stabilized, the fracture should be splinted prior to radiologic examination. The injured area should be radiographed in two planes; commonly, the anteroposterior and lateral views are adequate to visualize the majority of fractures in this group. All radiographs should include the joints above and below the area of injury.

Neurovascular status should be assessed frequently, as changes in vascular flow are ominous and must be readily identified. Wound care should be instituted as appropriate. Utilizing topical anesthetics can improve the quality of care as a comfortable, quiet child will allow for more thorough wound care than if the child is combative and in pain. The injured part should then be elevated, and tetanus immunization should be administered if there is a question about the immunization status of the child.

The most serious pediatric fractures are those that occur in the area of the physeal plate. These physeal injuries represent up to 30% of all pediatric fractures [104]. These fractures may lead to premature growth cessation or deformity [105; 106].

The Salter-Harris classification system allows for the assessment of these injuries. The common types are numbered I through V and are summarized in ***Table 6***.

The Salter-Harris type I injury is a transverse fracture through the hypertrophic zone of the physis resulting in a widening of the physis. The growth plate remains attached to the epiphysis, and there are usually no significant sequelae. The initial x-rays may only show a widening of the physis, but point tenderness at the epiphyseal plate suggests a type I injury is present. The prognosis for this type of injury is excellent.

Salter-Harris type II injuries include a fracture through the physis and metaphysis, but the epiphysis is uninvolved. It is the most common type of Salter-Harris fracture. On x-ray, the fracture line is seen through the metaphysis and may reach to the epiphyseal plate. The prognosis is usually excellent, although minimal shortening of the limb may occur in rare occasions.

Salter-Harris type III injuries involve a fracture through the physis and epiphysis, causing a disruption of the epiphysis. The fracture extends into the articular surface of the bone. It is uncommon for these fractures to result in permanent disability, and therefore, the prognosis is generally good; however, there is always a risk of long-term sequelae. The x-ray usually shows a well-demarcated fracture line through the physis, splitting the epiphysis and possibly extending to, but not disrupting, the metaphysis.

Salter-Harris type IV fractures involve the epiphysis, physis, and metaphysis. It can result in chronic disability and requires excellent reduction techniques. Because of the extensive damage, there is a strong probability of limb shortening and/or deformity of the joint. The x-ray shows a similar pattern to the type III injury with an obvious intra-articular fracture into the metaphysis.

Salter-Harris type V injuries are a compression or crush of the epiphyseal plate with no associated epiphyseal or metaphyseal fracture. The clinical history usually includes an axial load injury. Because of the major damage to the growth plate, these injuries often result in early closure and growth retardation. The x-ray usually shows soft tissue swelling at the physis and narrowing in the region of the epiphyseal plate. In adolescents, this may be difficult to discern and the diagnosis is usually made after the early closure of the growth plate. However, a nuclear medicine bone scan may help determine if metabolic activity is still taking place in a previously injured epiphysis. Permanent limb shortening and/or deformity is common [107].

The most common fractures in children are fractures of the forearm and clavicle [108; 109]. Both fractures occur when a child falls onto an outstretched arm. Fractures of the clavicle commonly occur in the distal third of the clavicle. Proximal fractures may be associated with an underlying subclavian artery injury and require more in-depth evaluation than distal fractures. Forearm fractures usually require four to six weeks of casted immobilization.

SALTER-HARRIS CLASSIFICATION OF ORTHOPEDIC FRACTURES IN CHILDREN		
Type	**Injured Area**	**Outcome**
I	Physis only	Excellent
II	Physis and metaphysis	Usually excellent
III	Physis and epiphysis	Risk of long-term sequelae
IV	Physis, epiphysis and metaphysis	Growth abnormalities, deformity
V	Compression of epiphyseal plate	Early closure, growth retardation
Source: [107]		*Table 6*

A unique fracture of small children is a "bowing" fracture, most commonly occurring in the forearm, although these injuries may also occur in the lower extremities. The bone is deformed and curved, like an archer's bow (also known as plastic deformity). This occurs in young children who have minimal mineralization of the extremities, allowing the bone to bend rather than break. The bowed extremity is casted in an anatomic straight position and will commonly remold to a normal shape.

Fractures involving the elbow require immediate assessment for neurovasculature function. The bony fragments may compromise the brachial artery, altering blood flow to the distal extremity. Most of these fractures are supracondylar, involving the distal humerus, and are common in children 3 to 10 years of age. An orthopedic surgeon should immediately evaluate any limb with signs of ischemia.

Humeral fractures of the proximal shaft should be assessed for epiphyseal injury. Early radiographs will demonstrate injury requiring orthopedic evaluation and stabilization. Compartment syndrome is a possible complication and can develop in less than 12 to 24 hours. If the child complains of unrelenting pain in the injured extremity, compartment syndrome should be suspected and treated if present [110].

Common lower extremity fractures include fractures of the tibia and fibula. These injuries can occur during sports-related activities (as seen in skiing and soccer), falls from heights, and pedestrian-motor vehicle collisions (most car bumpers strike the child's leg, causing fracture at the point of contact). Limited weight bearing and crutch use is recommended for a short period of time to allow for good bone growth and resolution.

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. Intramedullary rods and nailing are often used to stabilize the femur and allow the child early mobility.

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.

Advances in fracture management include early surgical stabilization and the rapid return to mobility. Most children sustaining fractures heal quickly without long-term sequelae. Methods of bone healing that continue to advance include bone grafting techniques, low-intensity ultrasonography, pulsed electromagnetic fields, distraction osteogenesis, and surgical therapy [111; 112].

Due to the strong ligamenture of children, dislocations are not as common as in the adult population. The most common dislocation in a child is an anterior shoulder dislocation, occurring when a child falls onto the shoulder area or impacts the upper arm. Traction can frequently be utilized to reduce these types of dislocations, although care must be taken to ensure that nerve and vessel entrapment does not occur during reduction. Follow-up assessment of neurovascular function is critical and x-rays are necessary to ensure proper realignment.

Children sustaining fractures and dislocations commonly have associated soft tissue injuries. Open wounds require immediate assessment of the extent of injury. Neurovascular compromise requires immediate attention and hemostasis should be accomplished to control blood loss. After other major traumatic injuries have been stabilized, wound care should be instituted utilizing irrigation and debridement as necessary. Wound closure may be accomplished using skin adhesives, which have shown excellent results in children sustaining superficial lacerations.

Although rare, traumatic amputations can occur in children. Many of these injuries occur in rural locations, farming accidents being one of the leading causes. Any child who sustains a traumatic amputation should be stabilized and transported to a facility with microsurgical capabilities. Replantations of children's amputations are frequently performed. Children have a better prognosis of success after these types of surgeries, and the lifelong disabilities associated with amputations may possibly be eliminated.

Care of traumatic amputations requires attention to a number of issues. First and foremost, the child should be stabilized, life-threatening injuries must be treated, and ongoing blood loss must be controlled. After these priority injuries are managed, the child should be prepared for transport. The newly formed stump should be gently cleansed and pressure dressings applied to control bleeding. Debridement should not be undertaken without surgical consult. The stump should be elevated to reduce swelling. If time permits, x-rays of the amputated part and the stump can be obtained; this will assist in decision making prior to surgical reattachment.

The amputated part should also be properly handled to prevent tissue destruction while awaiting surgical repair. The part should be gently cleansed and wrapped in slightly moistened gauze. It is important to prevent the amputated part from becoming saturated, either with blood or serous drainage. The wrapped part should be placed in a plastic bag and the bag placed into a plastic container, such as a urine cup or emesis basin. This plastic container should then be placed on ice in an ice cooler. The part should not be buried in ice. If the part becomes too cold, frostbite can develop, rendering the part unacceptable for replantation.

Traumatic amputations produce a tremendous amount of psychologic impact on the child and family members. There is immense concern regarding long-term outcomes, and grieving of these injuries begins early after injury. It is important that the staff caring for this patient provide emotional and psychologic support to all involved.

For those children sustaining amputations without replantation, the long-term outcomes are often promising. Children adapt well to artificial limbs. The continuing advances in design and use of these artificial parts have made prostheses more practical [113].

Complications following musculoskeletal and surface trauma can be limited with proper medical care. Wound complications can be minimized with early, thorough wound care. The development of post-injury infection has decreased drastically as more judicious use of antibiotic therapy has been instituted.

As noted, compartment syndrome can occur in children, with rapid development of signs and symptoms. Most commonly this complication develops after fracture; however, soft tissue injuries, such as injury occurring to the leg after being kicked during a soccer match, can also precipitate this complication. A child with closed compartment syndrome will complain of pain that is out of proportion to the extent of injury. Common pain management techniques are inadequate to control the child's pain. Any pain that remains unresolved should be a clue to the possibility of increases in intracompartmental pressure. Neurovascular compromise may be evident distal to the injury; however, the presence of pulses and adequate capillary refill does not guarantee that compartment syndrome is not developing. Management of compartment syndrome requires surgical fasciotomy to relieve pressure. Delaying surgical intervention can lead to necrosis of the affected musculature and long-term functional disabilities.

Another complication that must be considered is the development of tetanus following soft tissue injury. Although the immunization status of many children is up to date, there are still a number of injured children whose tetanus status may be inadequate or nonexistent. At the time of stabilization, the child's immunization history should be obtained. If the child is found to have inadequate coverage, tetanus immunization should be administered. With this simple intervention, the risk of life-threatening respiratory compromise and potential death may be avoided.

Although musculoskeletal trauma occurs frequently, outcomes are generally quite good. The practitioner must be alert to the development of life-threatening injuries and complications. With astute assessment and stabilization, many of the sequelae can be averted. The goals of musculoskeletal trauma care should be stabilization and subsequent measures to reduce death and disability from these injuries.

CASE STUDY

Patient E is a boy, 8 years of age, who is riding his skateboard in a city park. He is not wearing protective gear, including a helmet. When a friend distracts his attention, he runs head-on into a planter and is thrown over the planter box onto the concrete, landing on his left side. He immediately experiences pain in his left side, left wrist, and abdomen. His left wrist is angulated and obviously broken. His friend responds to Patient E's cries for help and calls 911. EMS personnel respond to the scene, stabilize his wrist, and transport him to the local emergency department for evaluation.

A head-to-toe assessment demonstrates small, superficial scrapes on the patient's forehead and left cheek. His facial structures appear to be intact. Neurologically, he is normal, with a GCS score of 14. He has no complaints of shortness of breath, and his chest wall shows no obvious external injury. He complains of pain when the left upper quadrant of his abdomen is palpated. His pelvis appears to be without injury. His lower extremities are bruised and have superficial contusions and abrasions, which are contaminated with dirt and rocks. An x-ray of his left wrist shows a comminuted fracture of his left radius and ulna.

Cervical spine x-ray, laboratory results, and urinalysis are all normal. At this time, the focus of treatment is on his left wrist and the pain in his abdomen. Abdominal CT scan is obtained and is normal, and liver injury is ruled out. Subsequently, Patient E is taken to the operating room for orthopedic repair of his left wrist.

After surgery, he is admitted to the orthopedic floor with orders for pain medication as needed. Repeat liver function tests are obtained on an every six-hour basis. After being settled in bed, he appears to be stable and enjoys the attention that the injury has brought him.

During the middle of the night, the patient awakens and complains of severe pain in his left wrist. He is medicated with narcotics as ordered and appears to drift off to sleep. Two hours later, he is again awake and complaining of wrist pain. As the narcotic was ordered on an every four hour basis, the nurse must obtain an order for additional narcotic, which she does. After this second dose of pain medication, the patient again drifts off to sleep.

During the next day, he has a number of visitors. He continues to complain of pain in his wrist, but when observed, he is seen to be laughing and joking with his friends. The nurse caring for Patient E asks him to rate his pain on a scale of 1 to 10 with a reply of 8. The nurse continues to observe him and has a hard time believing the pain is as severe as 8. Two hours later, the patient again calls the nurse, this time giving a pain score of 9, and he is medicated by another nurse. The nurse medicating him checks his cast and finds it to be tighter than it had been earlier in the day, and capillary refill in his left hand is slower than on this right hand. She instructs him to keep the casted arm elevated on a pillow while visiting with his friends.

Later that evening, the patient again complains of pain with a score of 9. He is again medicated and drifts off to sleep after a busy day. During the middle of the night, he is crying and says that his hand hurts more than it ever has. His cast is tight, and his left hand is cool to touch. The orthopedic surgeon is notified by telephone, and the in-house physician evaluates Patient E. The in-house physician recommends that the patient be returned to the operating room for evaluation, and the orthopedic surgeon arrives at the hospital within the hour.

In the operating room, Patient E's hand is pale, with weak pulses and a significantly reduced range of motion. A diagnosis of compartment syndrome is made, fasciotomy is performed, and the wrist is placed in another cast that is bivalved. Eventually, the patient's wrist heals, and he regains full range of motion after intensive physical therapy.

Case Study Discussion

The care Patient E received in the initial stages after his trauma was excellent. A complete assessment was performed, and all injuries, both real and potential, were identified. The complications developed post-surgery, when he was admitted to the orthopedic ward. The frequent complaints of pain were incongruous with his behavior and, therefore, not validated by the nurses caring for him. New guidelines for pain management stress the importance of including the patient in the assessment of their pain and believing the report provided by the patient. Just because the patient's outward behavior was not what the nurse expected, it must be remembered that he may have been utilizing his friends as a distraction to his pain because he was not being adequately medicated.

Patient E's complaints of pain should also have alerted the staff to the development of potential problems. After a patient's fracture has been surgically stabilized, the pain should begin to resolve, not increase in intensity. With each complaint of pain, he should have had his pulses and circulation checked and his cast evaluated. His deteriorating condition should have been noted earlier, and surgical intervention could have been undertaken earlier rather than later. Patient E was lucky in regaining full function after this complication. Children are generally more resilient than adults. Had this complication developed in an elderly individual, the results may not have been as fortunate.

MEDICAL SEQUELAE OF PEDIATRIC TRAUMA

Although most children respond to trauma treatment with good results, children who are severely injured run the risk of developing post-trauma sequelae, including post-traumatic respiratory distress, MODS, and renal failure. With early recognition and aggressive therapies, these sequelae can be reversed and the mortality rate can be minimized.

Post-traumatic respiratory distress syndrome occurs following pulmonary injury, leading to pulmonary congestion. As the disease progresses, there is increased mucus formation and a loss of surfactant. The syndrome has four pathophysiologic characteristics:

- A systemic inflammatory response with the release of mediators
- An alteration in the alveolar-capillary membrane
- Changes in airway diameter
- A disruption in systemic oxygen transport and utilization

The hallmark sign is persistent hypoxemia in spite of increasing oxygen delivery. The child will develop a compensatory tachypnea, an increased shunt fraction, increased dead space ventilation, a decreased static compliance, and pulmonary hypertension.

Chest x-ray usually demonstrates diffuse bilateral infiltrates with a normal lung next to a severely injured lung. There will be no evidence of congestive heart failure as is seen with other respiratory distress syndromes. In the initial stages, the lungs are dry. The child is dyspneic and tachypneic, leading to a respiratory alkalotic state with a decreasing $PaCO_2$ level. Within 24 to 48 hours, the child becomes severely dyspneic and hypoxemic. Chest x-ray evidence will develop, and if recognized and treated early, resolution will occur. In severe cases, the child develops irreversible hypoxemia and death occurs within two weeks. For those children who survive this insult, the prognosis is good, with a return to normal pulmonary function; however, complete resolution can take up to one year.

Management of post-traumatic respiratory distress syndrome is aimed at supporting the hypoxemia and reducing the pulmonary congestion. If the syndrome progresses to the severe hypoxemic state, mechanical ventilatory support is necessary to provide adequate oxygenation. Continuous and bi-level positive airway pressure has been recommended to stabilize pediatric patients [81; 114].

Positioning the patient for the best gas exchange has been the focus of intensive study. The studies in adults have demonstrated that frequent position changes and prone positioning have beneficial effects upon the patient's respiratory status. Positioning children with multiple injuries, multiple invasive lines, and stabilization devices requires forethought and ingenuity. It often seems that when the patient is finally settled into the new position, it is time to again change the position.

Other measures to improve patient status include administering packed red blood cells to improve oxygen delivery at the cellular level. This is instituted if the hemoglobin is low, as would be seen after hemorrhage. Pharmacologic agents may be utilized for cardiovascular support; these agents are generally reserved for severe cases with refractory hypoxemia. Until the pathophysiology of this syndrome is completely understood, various experimental measures will be utilized in an effort to support the failing child.

MODS is defined as progressive deterioration of two or more organ systems over a short time period [115]. This organ failure is initiated by systemic inflammatory response syndrome (SIRS), which is a systemic response to a variety of insults, including trauma. SIRS causes the release of mediators that either facilitate cell-to-cell interaction or cause direct tissue damage. The etiologic factors in trauma include: sepsis; persistent, prolonged hypovolemic shock; multiple transfusions; and extensive tissue damage [115]. Descriptive scoring systems have been established for pediatric MODS based on severity of symptoms in five organ systems: cardiovascular (lactic acid), respiratory ($PaCO_2$/fraction inspired O_2 ratio), hepatic (bilirubin), hematologic (fibrinogen), and renal (blood urea nitrogen or BUN) [116].

The defining characteristics of MODS are organ specific [115]. Most commonly, pulmonary failure develops first and is characterized by respiratory failure with a $PaCO_2$ greater than 50 mm Hg, an alveolar-arterial oxygen difference ($AaDO_2$) gradient greater than 350 mm Hg, and ventilator dependence. At day six or seven, hepatic failure begins to develop and is defined by a bilirubin of greater than 6 mg/dL, a prothrombin time of more than four seconds greater than the control, and jaundice. If the bilirubin is greater than 8 mg/dL, the syndrome carries a mortality of 90% or greater.

GI failure is identified next; the child develops a paralytic ileus, and a GI bleed ensues. At two weeks, the kidneys begin to fail and the urine output drops while the BUN and creatinine begin to rise. At this point, the child will require dialysis. Ultimately, neurologic and cardiovascular failures develop. The child becomes comatose, with a GCS score of less than or equal to 6 in the absence of sedation. Cardiovascular failure is the terminal event; death occurs at two to four weeks after onset of organ dysfunction.

Mortality is dependent upon how many organ systems are involved. With two organ systems involved, the mortality rate is approximately 67% to 78% [117]. When four or more organs fail, mortality approaches 100% [117]. The keys to combating this mortality are prevention, early recognition, and controlling mediator release.

Prevention of multi-organ failure occurs during all phases of care. In the initial resuscitative period, aggressive volume resuscitation is imperative [115]. As discussed, assessing the effectiveness of volume resuscitation is controversial. Despite the debate regarding the optimal method of assessment, ensuring adequate resuscitation is critical. Depending upon the capabilities of the facility, this may mean monitoring the base deficit and serum lactate levels, using pulmonary artery catheters to measure central oxygenation and cardiac outputs, calculating oxygen delivery and consumption, and measuring the gastric pH.

Preventative measures undertaken during the operative phase of care include timely surgical intervention, thorough debridement of nonviable or infected tissue, early fixation of long bone and pelvic fractures, and avoiding "missed" injuries. After the patient is transferred to the trauma intensive care unit, early nutritional support is instituted, antibiotics are ordered as appropriate, and pharmacotherapy for organ support is provided. Should the patient have sustained a "missed" injury, timely reoperative surgery is critical to prevent ongoing failure [54].

However, after the organ failure begins, treatment is generally supportive. Controlling and treating infection is one goal of therapy. Antibiotics are initiated early, and IV lines are monitored frequently for signs of localized tissue reactions and are changed as needed. Aseptic technique is critical to prevent hospital-acquired infections from developing.

Increasing oxygen supply is critical to reducing organ failure and involves a number of interventions. Initially, the supplemental oxygen level is increased until it reaches 100%. Intubation and ventilatory support are required to achieve maximal oxygen delivery. However, oxygen must reach the tissue level to achieve benefit. Having the child sit up, cough, and breathe deeply will improve pulmonary function. Suctioning is often required as pulmonary congestion worsens. Blood products are also utilized, as with post-traumatic respiratory distress, to improve oxygen delivery.

Coupling the increased oxygen supply with a decreased oxygen demand will help reverse persistent hypoxemia. Decreasing the oxygen demand includes controlling anxiety and pain, administering analgesics and sedative agents, providing rest periods, and reducing the development of hyperthermia and shivering. Providing the child with quiet, bedside activities will help provide a method of distraction; however, it is imperative that these activities not excite the child further. The excitement generated may increase oxygen demands and defeat the purpose of the activity.

Metabolic support is a critical part of patient care management. Early feeding will improve tissue function and provide energy for cellular activity. Tube feedings are initiated in some patients as early as 24 hours after injury. At this point, an ileus has not yet developed and early feeding may actually prevent its formation. The concentration of the feedings is increased slowly until optimal caloric intake is achieved.

Much emphasis and research has focused on the action of the gut in the development of MODS. When the body is stressed, as in trauma, the integrity of the bowel mucosa may be compromised, allowing the passage of organisms into the blood stream. Much of the focus has been on the passage of gram-negative organisms into the vascular system, which in turn precipitates mediator release. If this theory is valid, interventions aimed at gut decontamination and control of gram-negative sepsis may be a key to reversing the effects of these sequelae.

At this point in the research process, the results of gut decontamination are inconsistent. Despite this, antibiotic therapy for gram-negative organisms is utilized to reduce the risk of systemic sepsis.

One of the more common and more easily treated complications of trauma in children is the development of acute renal failure. Renal failure is classified as prerenal, intrarenal, or postrenal failure [118]. The treatment of choice depends upon the type of failure; thus, differentiating the cause of failure is critical to successful management.

Prerenal failure is caused by inadequate perfusion of the kidneys. This is one of the most common forms of renal failure following trauma and occurs secondary to the hypovolemia that develops with blood loss and fluid shifts. Intrarenal failure develops secondary to injury to the renal parenchyma and can be caused by either direct injury or, more commonly, injury that is secondary to prolonged ischemia. If the child remains hypotensive for a long period of time, intrarenal failure is common. Postrenal failure is less common; this type of failure develops as a result of an obstruction in the drainage system.

The majority of children who develop acute renal failure respond quickly to resuscitation and treatment. Most children develop oliguric failure, whereby the urine output drops and the BUN and creatinine levels rise. (It is possible to have nonoliguric failure, also known as high-output failure, whereby the urine output is high but creatinine clearance is low.) As the kidneys recover, the urine output increases and the urine becomes more concentrated. The degree of recovery is dependent upon the severity of damage to the kidneys.

The treatment goals include maintaining a normal circulating volume, normal electrolyte values, and vascular stability. In cases of prerenal failure, adequate fluid administration may be all that is necessary to reverse the impending failure. In some cases, a furosemide or mannitol challenge may be administered to prevent acute tubular necrosis from developing during the oliguric phase.

Hemodialysis has for many years been the treatment of choice for acute renal failure despite the fact that many patients do not tolerate the volume shifts that occur with this type of dialysis. Patient instability has led to a renewed interest in other methods of dialysizing the blood, now known as renal replacement therapies [119]. Trauma patients with unstable cardiovascular function cannot withstand further volume shifts that can occur with dialysis; thus, measures to limit these volume shifts have been instituted.

Peritoneal dialysis may be advantageous for the trauma patient, as the blood is dialyzed at a slow rate without volume shifts. However, in the trauma population, this method may not be able to be utilized if abdominal trauma is suspected or confirmed, as an intact peritoneal cavity is required.

Continuous renal replacement therapies (CRRT) are methods of circulating blood outside the body through a highly porous filter [120]. The patient's blood pressure, rather than a machine, drives the dialysis system. This type of dialysis is good for the hemodynamically compromised patient; however, anticoagulation is required and may not be safe in certain trauma patients. The methods vary from arteriovenous to veno-venous type systems, depending upon where the patient is cannulated for catheter placement. The best method of CRRT has yet to be determined; however, the use of CRRT is rapidly becoming a standard of therapy for the management of acute renal failure following trauma.

Pain is also considered a sequela of injury and is one complication that practitioners can proactively control. Studies have shown that many children treated for fractures in emergency departments do not receive adequate pain control. Physicians must take the time to assess the level of pain in a child and subsequently provide adequate medication for pain management.

Some of the common misconceptions in managing pain in children are that they cannot localize pain, they cannot use pain scales, and narcotics and other medications will compromise the child's status. In fact, children can identify and describe pain and its location. They can utilize pain scales that have been developed specifically for children, and narcotics are no more dangerous in children than they are in adults. Providing small, frequent doses of narcotics, nonsteroidal agents, and sedatives allows titration of drugs to the effect desired. Children should not suffer after injury. Once assessed, narcotics can be given to decrease the pain the child is experiencing.

Nonpharmacologic interventions for pain can also be utilized with great success in many children. Positive reinforcement of good behavior will yield desired rewards. Distraction will shift the child's attention away from the pain. Visiting with friends, watching television, and holding onto a parent will refocus the child's attention. The more the child is distracted, the less pain he or she will experience. Relaxation techniques in children can include deep breathing exercises. This will achieve two goals: relaxing the child and improving the child's gas exchange. Providing a child with a favorite toy or blanket provides the child with a sense of security and will reduce fear and anxiety.

It is imperative that healthcare providers aggressively pursue pain control options. While not all measures work on all children, providing pain reduction measures can be achieved through trial and error. Combining pharmacologic and nonpharmacologic therapies may be performed with a high rate of success. The State of California enacted legislation that requires all healthcare providers to assess pain and develop pain plans with patients, including children. To neglect a child's pain in California could bring legal consequences.

The sequelae of trauma presented here are only a few of the many complications that can beset the pediatric trauma victim. As children reach adolescence, the use of drugs and alcohol can be a factor in complication development and management. Other sequelae previously discussed include abdominal compartment syndrome and bone growth abnormalities, among many others. The pediatric trauma care practitioner must be aware of the multitude of sequelae and be constantly vigilant to their impending development. The injured child can often respond positively to treatments as long as they are instituted in a timely manner.

NON-ENGLISH-PROFICIENT PATIENTS AND FAMILIES

Healthcare professionals involved in the care of pediatric patients whose families have a limited proficiency in English are faced with many difficulties, both in the assessment of trauma victims and in making decision regarding care. When the patient and/or family members speak a language other than that of the clinician, a professional interpreter should be engaged. A systematic review of the literature has shown that the use of professional interpreters provides better clinical care than the use of "ad hoc" interpreters. Professional interpreters improve the quality of care for patients with limited English language skills to a level equal to that for patients with no language barriers [121]. Use of professional interpreters has been associated with improvements in communication (errors and comprehension), utilization, clinical outcomes, and satisfaction with care [121].

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.

While in-depth discussion of the sequelae of trauma is beyond the scope of this review, a few of the major points were highlighted. Reducing the long-term consequences of these sequelae begins at the time of the injury and progress throughout all care areas. The incidence of sequelae can be limited with rapid, accurate identification of all injuries sustained and thorough stabilization of these injuries.

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.

Implicit Bias in Health Care

The role of implicit biases on healthcare outcomes has become a concern, as there is some evidence that implicit biases contribute to health disparities, professionals' attitudes toward and interactions with patients, quality of care, diagnoses, and treatment decisions. This may produce differences in help-seeking, diagnoses, and ultimately treatments and interventions. Implicit biases may also unwittingly produce professional behaviors, attitudes, and interactions that reduce patients' trust and comfort with their provider, leading to earlier termination of visits and/or reduced adherence and follow-up. Disadvantaged groups are marginalized in the healthcare system and vulnerable on multiple levels; health professionals' implicit biases can further exacerbate these existing disadvantages.

Interventions or strategies designed to reduce implicit bias may be categorized as change-based or control-based. Change-based interventions focus on reducing or changing cognitive associations underlying implicit biases. These interventions might include challenging stereotypes. Conversely, control-based interventions involve reducing the effects of the implicit bias on the individual's behaviors. These strategies include increasing awareness of biased thoughts and responses. The two types of interventions are not mutually exclusive and may be used synergistically.

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