

Pediatric Trauma Care

A Practical Guide

Alfred P. Kennedy Jr

Romeo C. Ignacio

Robert Ricca

Editors



Springer

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Preface

“Rejoice O young man in the youth”
Ecclesiastes 11:19

The naissance surrounding this text was conceived with a desire to present to the reader with a succinct and portable “handbook” for the most common clinical problems encountered by those of us who care for the injured child. It is not meant to be an exhaustive treatise. Each chapter is designed to present the reader with concise information surrounding the injury complex. Chapters are divided into Clinical Pearls, focused diagnosis and management, ending with take home points. It is with sincere gratitude that the majority of content is presented by authors who serve or have served in this nations’ Defense. The debt of service shall never be paid.

Danville, PA, USA
La Jolla, CA, USA
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Independence Day 2021

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Chapter 1

Introduction: (Unique Factors to Pediatric Trauma)



Robert Ricca

Abstract Trauma is the leading cause of death in children. The last several years have seen significant improvements in the care of the traumatically injured pediatric patient in part due to research efforts focused on pediatric trauma. These efforts are paramount as children differ from adults in many ways including size and proportion, as well as in their physiologic response to injury. The provider caring for a traumatically injured pediatric patient must be aware of these key differences such as: management of the pediatric airway, the risk for hypothermia, pliable rib cage and significant pulmonary contusion in the absence of rib fractures. Some critical points in adult management have significantly contributed to pediatric trauma management, including balanced resuscitation strategies, early use of blood products, prophylaxis of venous thromboembolism, and more recently, use of whole blood instead of component therapy. Similarly, some pediatric trauma strategies have changed the way adult patients are managed including non-operative management of solid organ injury. These issues have illustrated the need for trauma capabilities that are dedicated to the management of the injured child. This textbook strives to provide a clinically focused management strategy that is a rapid reference for those individuals who care for these injured children. This chapter will touch on research efforts and organizations that have improved quality outcomes for pediatric trauma patients not discussed elsewhere in this text.

Keywords Pediatric trauma · Trauma training · Trauma organizations · Epidemiology

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Key Concepts

- Care of traumatically injured children has fallen under the auspices of pediatric surgeons for the last century. Recently we have seen a resurgence of interest in pediatric surgical trauma care.
- Key differences exist in body composition, physiologic response to injury as well as underlying trauma mechanisms between the pediatric and adult that trauma patient.
- Multiple organizations exist that focus on collaborative research efforts, advocacy and clinical practice guidelines to improve outcomes for the treatment of traumatically injured children.
- There are several courses focused on the different phases of care that can add to the knowledge of professionals caring for traumatically injured patients. These range from pre-hospital care to advanced surgical exposures.

Introduction

William Ladd has long been identified as the founder of pediatric surgery in North America. His commitment to the surgical care of children began in 1910 when he joined the staff of the Children's Hospital in Boston. A mere 7 years later, Dr. Ladd was an integral part of one of the largest mass casualty efforts that affected children during the twentieth century. On December 6th, 1917, during the height of World War I, the SS Mont-Blanc, a French cargo ship, collided with a Norwegian vessel the SS Imo. The SS Mont-Blanc was carrying wartime munitions, and the result of the collision was a tremendous detonation that injured over 9000 individuals in some reports. Scores of children were amongst those injured, and it was Dr. Ladd, amongst many other healthcare professionals, who traveled from Boston to assist with the mass casualty event resulting from the explosion. These children suffered from both thermal injuries as well as other traumatic injuries from the blast and shock wave that destroyed countless houses and businesses in the area. Almost a century later, trauma remains the leading cause of death in children in North America. Legend holds that this event spurred the birth of pediatric surgery in North America. While this may be surgical lore, the understanding by Dr. Ladd and his counterparts that pediatric trauma victims during this event required unique management strategies is a key point that still holds true today [1].

Over the course of the last century we have seen a continued expansion of trauma capabilities throughout the world. Training in trauma and critical care is available following general surgery residency [2]. Many of these surgeons provide care for injured children, however, there has been a move recently to increase the involvement of pediatric surgeons in the care of traumatically injured children. The recognition of differences in physiology and subsequent management of traumatically injured children when compared to adults has led to the evolution of pediatric-specific trauma centers. The American College of Surgeons (ACS) now verifies centers as Level 1 or Level 2 pediatric trauma centers. The criteria for verification are

well established by the ACS and have demonstrated decreased injury-related mortality and improvements in quality related metrics compared to non-ACS-verified centers. At the time of this publication, there are more than 60 Level 1 pediatric trauma centers in the United States and over 50 Level 2 pediatric trauma centers [3]. These centers serve as the experts in pediatric trauma care within the regional trauma system where they are located and interact routinely with all components of the trauma system to improve the care of the injured child.

Trauma affects children of all ages. Unintentional injury remains the leading cause of death in children of all ages. For children aged 10–14, intentional or self-inflicted harm is also the second leading cause of mortality. The most common mechanism, at the time of this writing, across all ages is motor vehicle collisions (MVCs). The breakdown of trauma mechanism is then broken down by age, with assaults, firearm injuries, sports-related injuries, falls and burns as the second leading cause of injury depending upon the age of the patient. Similar to prevention efforts in adults, recognizing the age at which traumatic injury is more likely to occur allows for educational efforts and injury prevention programs that serve to decrease the rate of injury as well as the extent of injuries [4, 5].

The understanding of the epidemiology of injuries is an important facet in the overall treatment of the pediatric trauma patient. It can be used to determine injury patterns as recognize potential injuries when children arrive in the trauma bay from the pre-hospital setting. Furthermore, the understanding of mechanisms can prompt injury and trauma prevention programs that can be used to decrease the frequency of traumatic events. Trauma is typically due to the application of a force to the human body with subsequent transfer of energy. As we will see in this manuscript, the understanding of how this force is applied can be important to not only injury prevention but also in determining what injuries would be expected from a specific mechanism. The recognition of motor vehicle collisions as a leading cause of morbidity and mortality has prompted the initiation of legislation that enforces the use of seatbelts for children [6]. The Center for Disease Control (CDC) notes that proper use of age and size-appropriate restraining devices reduces serious and fatal injuries in pediatric patients by nearly 80%. Similarly, children are at risk for non-accidental trauma [6]. The recognition of injury patterns and mechanisms of injury that are inconsistent with the age or developmental status of the patient should prompt a workup for child abuse. These efforts can prevent future injury and identify children who are at risk for future traumatic events.

Pediatric patients are managed in an algorithmic fashion similar to adult patients. The Advanced Trauma Life Support (ATLS) program teaches a systematic concise methodology to the approach of the trauma patient. All trauma patients, upon arrival to the hospital setting, should be managed according to the primary survey of Airway, Breathing, Circulation, Disability and Exposure/Environmental concern [7]. As we have noted, there are physiological differences in pediatric patients that providers must be aware of when caring for injured children. Recognition of difficult airways and understanding that hypoxia is a leading cause of cardiac arrest in children is vital in the initial management of the trauma patient [8]. Early blood transfusion using a balanced resuscitation of component therapy products has been introduced recently

in the 10th edition of ATLS. These guidelines now call for only one 10 mL/kg bolus of crystalloid fluid before transitioning to packed red blood cells [8]. Assessing neurologic status may be made difficult by the child's developmental age. Glasgow Coma Scale assessment must be modified to address the child who may not be verbal due to age or underlying medical conditions [8]. Due to the proportionately greater surface area of skin seen in children, they are at greater risk for hypothermia when exposed to evaluate for all injuries during the secondary survey. Appropriate warming measures need to be instituted to ensure they maintain normothermia [8].

Trauma Organizations

Two of the best-known organizations who provide research efforts, guidelines, education and sharing of clinical experiences are the Eastern Association for the Society of Trauma (EAST) and the Western Trauma Association (WTA). These organizations have members who are both adult and pediatric trauma surgeons with a primary focus on improving outcomes of traumatically injured patients. They have robust websites located at: <https://www.east.org> and <https://www.westerntrauma.org> [9, 10]. Both sites have recommended practice management guidelines that focus on specific injury. These guidelines are rapidly accessible and can be quickly reviewed to determine appropriate management strategies. Both organizations have a wealth of knowledge for the individual caring for a traumatically injured patient. The Pediatric Trauma Society (PTS) is an organization for healthcare providers who care for traumatically injured children. Similar to EAST and WTA it also focuses on research, quality improvement, clinical practice guidelines and advocacy. These guidelines are available on their website and include rapid reference visual abstracts. The link to the guideline portion for the website is: <https://pediatrictraumasociety.org/resources/guidelines/> [11].

The American Pediatric Surgical Association (APSA) also provides education and advocacy for trauma related issues. Advocacy issues that have been addressed or supported by APSA related to trauma include Gun Related Violence, Child Abuse and Drowning. Additionally, several committees focus either directly or indirectly on pediatric trauma initiatives [12]. APSA has a robust trauma committee and surgical critical care committee that directly influence the care of critically injured children. Likewise, the Education committee and Outcomes committee have, at times, focused on the management of pediatric trauma patients through systematic reviews and promulgation of current literature to the greater body of pediatric surgeons [13]. The American Academy of Pediatrics (AAP) is another national organization that provides advocacy for trauma related issues that affect pediatric patients and their families [14].

Improving outcomes for critically injured pediatric patients is a main focus of current research efforts. Similar to the National Surgical Quality Initiative Program (NSQIP), the American College of Surgeons Committee on Trauma (ACS COT) has also initiated a Trauma Quality Initiative Program (TQIP). Since 2016, the ACS

COT has offered a Pediatric TQIP that allows for data collection on traumatically injured children. Institutions who are either ACS verified Level 1 or Level 2 trauma centers or those who are “in-process” may join and participate. This quality program not only provides training in data collection and the use of data to improve trauma outcomes at a single institution, but it also allows for sharing of best practice guidelines and quality initiatives through regular conference calls and an annual meeting [15].

Research consortiums such as the ATOMAC+ group have enhanced the ability to provide treatment guidelines and recommendations by allowing for multi-center collaborative research networks. This consortium initially began with six institutions from Arkansas, Texas, Oklahoma, Memphis and Arkansas designated as the ATOMAC group. Since then, they have expanded with further institutions joining the research efforts causing a renaming to ATOMAC+. They have provided guidelines and research on a breadth of trauma topics including blunt cerebrovascular injury, solid organ injury, trauma resuscitation and transfusion [16]. Continued efforts through consortiums will only serve to improve the understanding of pediatric trauma mechanisms, allow for guidelines for both prevention and treatment and ultimately result in improved outcomes for critically injured children.

It would be remiss to complete this section without recognizing the significant impact that the military experience in recent conflicts has provided to the current management of pediatric trauma patients. The treatment of both military and civilian personnel, including children, and the collection of data through the Joint Theater Trauma Registry has provided yet another opportunity to critically assess management strategies. This has continued a trend started by surgeons who provided care during conflicts in Korea and Vietnam, returning to the United States with improved knowledge on the management of traumatically injured personnel. Multiple pediatric surgeons who actively care for pediatric trauma patients have spent time in a deployed setting caring for injured children in a theater of war or humanitarian setting. These experiences have only served to improve the care provided to children injured in a civilian setting. Additionally, research evaluating the use of whole blood therapy, balanced resuscitation, massive transfusion, use of tourniquets and tranexamic acid (TXA) for hemorrhage control amongst other items has been able to be translated to civilian practice [17]. The Joint Trauma System provides continuously updated clinical practice guidelines, available at https://jts.amedd.army.mil/index.cfm/pi_cpigs/cpigs with some focusing on austere surgical care that a pediatric surgeon on a humanitarian mission might encounter [18]. Continued partnership with military physicians will only serve to improve civilian care moving forward.

Training Opportunities

There are several courses offered to teach skills specifically related to the management of trauma patients. Perhaps the most well-known course is the Advanced Trauma Life Support (ATLS) Course that is offered through the American College

of Surgeons. This course is dedicated to offering healthcare providers with a safe and effective methodology for the initial management of trauma patients. Over one million physicians in more than 80 countries have completed the course. It remains the scaffold upon which most trauma resuscitations are based [7]. Alongside ATLS, the Advanced Trauma Care for Nurses course is dedicated to providing registered nurses who care for trauma patients with a more in-depth understanding of the management of trauma patients. It runs concurrently with ATLS courses and shares the didactic portion [19]. Stop the Bleed is another course sponsored by the American College of Surgeons that provides education to the lay person on how to manage bleeding in a severely injured patient. These courses have even been offered to high school students with successful application of the skills to respond and provide life-saving care [20]. These efforts have been born from numerous mass casualty events where immediate care can be provided by a bystander while waiting for first responders to arrive upon the scene. Trauma Evaluation and Management (TEAM) is an introductory level course on the management of traumatically injured patients that is geared towards medical students. The content is derived from the ATLS course and can serve as a primer for medical students to increase their knowledge on trauma management [21].

Advanced courses for surgeons on surgical techniques and exposures are also offered. Advanced Trauma Operative Management (ATOM) is a course designed for senior residents, trauma fellows, military surgeons or general surgeons who may be called upon to manage trauma patients. It is designed to improve competence in the management of penetrating trauma to the chest and abdomen. The course is made up of lectures with a lab session with 1:1 supervision. The surgeon is taught how to identify and repair multiple injuries including repair to the bladder, diaphragm, spleen, liver, inferior vena cava and cardiac injuries [22]. Advanced Surgical Skills for Exposure in Trauma (ASSET) is another course that teaches operative exposure for traumatic injuries designed for senior residents, trauma fellows and general surgeons. This can be seen as a follow-on training to the ATOM course and provides training in surgical exposure to five anatomic areas: neck, chest, abdomen/pelvis, upper and lower extremities. This course uses cadaver training with hands on experience in operative exposure [23]. The Basic Endovascular Skills for Trauma (BEST) offers training in endovascular techniques such as the use of resuscitative endovascular balloon occlusion of the aorta (REBOA). These techniques have been used in adolescents in place of emergency thoracotomy to temporize life-threatening hemorrhage [24].

The Royal College of Physicians and Surgeons of Canada sponsors the Trauma Resuscitation in Kids (TRIK) course. This course is the only trauma course dedicated solely to the management of pediatric trauma. It is a 2-day simulation-based course focused on the roles of the team leader and team members [25]. For those healthcare providers who find themselves working in a remote or rural area that may be a critical access hospital, the Rural Trauma Team Development course is

offered by the ACS emphasizes a team approach to the initial evaluation and resuscitation of the trauma patient at a rural facility. The course assists health care professionals working in a rural setting in determining the need to transfer the patient to a higher level of care. While many pediatric surgeons or trauma surgeons work in an urban center and will receive transfers from the rural site, knowledge of this course and the education provided can assist with smooth communication and transfer of patients to a higher echelon of care [26]. Continuing with training for trauma systems, the Disaster Management and Emergency Preparedness Course (DMEP) provides education on the planning, implementation and review of disaster plans for mass casualty scenarios. While it encourages attendance by healthcare providers who will be first responders in a mass casualty scenario, it also encourages attendance by healthcare administrators, public health professionals and emergency management experts who will be intimately involved in the planning and preparation phase for mass casualties and other disaster scenarios [27].

Conclusions

While it may be surgical lore that the birth of pediatric surgery started with Dr. Ladd traveling to Halifax, Nova Scotia the recognition by Dr. Ladd that these children required care by experts in the pediatric surgical field is a profound concept still applicable today. Understanding epidemiology, physiology and mechanisms of injury as well as injury patterns is paramount to not only providing outstanding care to the trauma patient but to also ensure appropriate preventive strategies are in place. Continued collaborative efforts amongst pediatric trauma centers through formalized programs such as the Pediatric Trauma Quality Initiative Program and regional centers such as ATOMAC+ will serve to enhance our understanding of trauma and provide guidelines that will continue to improve outcomes. Pediatric surgeons and healthcare professionals should remain aware of the multiple training opportunities available to enhance their knowledge of every aspect of trauma care.

Take Home Points

- Numerous courses are available to train the healthcare provider in the initial resuscitation, management and operative treatment of trauma patients.
- Trauma quality initiatives such as the Pediatric Trauma Quality Initiative Program as well as research consortiums such as ATOMAC+ serve to enhance our understanding of pediatric trauma, provide guidelines and improve outcomes.
- Numerous organizations exist to provide guidelines or advocacy for pediatric trauma patients. The practitioner caring for critically injured children should be aware of these organizations that provide clinical practice guidelines for the management of trauma patients.

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Chapter 2

Injury Prevention



Judith Egly and Robert Ricca

Abstract Thousands of children are seen in emergency rooms in the United States and throughout the world annually due to trauma. Trauma and associated injuries remain the most common cause of death in children in the United States. Injuries have been delineated by mechanism (motor vehicle accident, firearm related, drowning, burn) and by intent (self-inflicted, unintentional, etc.). The term injury, rather than accident, is purposeful as accidents typically are unavoidable while research has shown that many of these fatalities and underlying injuries are preventable and can be mitigated by evidence-based guidelines and preventive measures. Use of safety belts and car seats have shown dramatic improvement in the survivability of motor vehicle collisions. Similarly helmet regulations protect the cranium and contents in the event of a bicycle, motorcycle, or all-terrain vehicle accident. Recent efforts have focused on firearm safety. These preventive efforts are part of a broader public health effort to ensure the safety of children and adolescents. This chapter will discuss injury prevention and provide examples of specific injury prevention strategies that are currently in place to decrease the risk of injury in children.

Keywords Injury prevention · Pediatric trauma · Seatbelts · Helmets · Education

Key Concepts/Clinical Pearls

- Traumatic injury is the most common cause of death for children across all age groups.
- Injury prevention is paramount to not only avoid the traumatic event but to also minimize the extent of injury thus saving lives, decrease time spent in the hospital and healthcare costs.

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- Preventive measures enter all facets of life including use of helmets, car seats and safety belts, childproofing of houses and electrical outlets, protective equipment for sporting events and gun safety to name a few. Proper education and legislation are important to reinforce injury prevention.
- Numerous organizations provide advocacy and guidelines for injury prevention. These include the Center for Disease Control and Prevention, the American Pediatric Surgical Association, Pediatric Trauma Society, Safe Kids Worldwide, The Injury Free Coalition and the Consumer Product Safety Council.

From 2010 through 2019, preventable injuries were the leading cause of death for children ages 1–19 according to the Centers for Disease Control and Prevention’s (CDCP) National Center for Injury Prevention and Control (2008–2018) (Fig. 2.1). In 2019, more than 7000 children died in the United States due to unintentional injury, which equates to 20 children each day [1]. The topic of injury prevention is so important with regard to pediatric trauma that it is highlighted in the pediatric trauma chapter in the Advanced Trauma Life Support student manual [2]. It is suggested that up to 80% of pediatric trauma injuries could have been prevented with the institution of simple measures either in the home or in the community [2]. These measures are not only important for saving the lives of countless children but also prevent devastating effects on lives of the individual and families that are affected by trauma. Furthermore, injury prevention is also associated with a significant reduction in healthcare expenditure regarding pediatric trauma. It is estimated that for every dollar spent on injury prevention, four dollars are saved in hospital care [2]. This

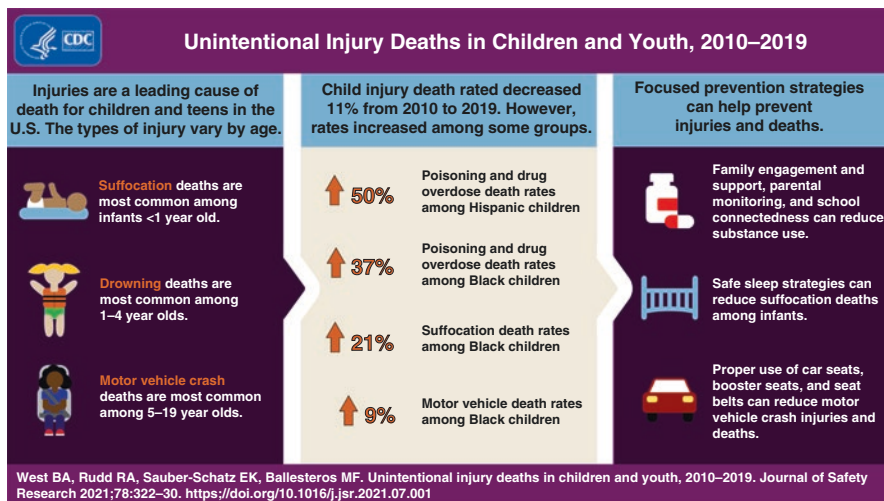


Fig. 2.1 Unintentional injury deaths in children and youth, 2010–2019. (Source: Injuries among Children and Teens. Centers for Disease Control and Prevention. <https://www.cdc.gov/injury/features/child-injury/index.html>, Accessed 26 Oct 2021)

becomes even more important when placed in the context that medical cost of injury of all patients, not just children, accounts for 12% of the national healthcare expenditure [3]. The consequences of preventable injuries to children can result in lifelong disabilities, physical impairments, and psychosocial/emotional impacts. The return on investment that is seen with injury prevention efforts in pediatric trauma is without question some of the most important efforts of pediatric trauma providers. It exemplifies the saying – an ounce of prevention is worth a pound of cure.

Multiple organizations nationally advocate for child safety and injury prevention such as the Consumer Product Safety Commission, Safe Kids Worldwide, American Academy of Pediatrics and of course, the CDCP [1, 4–6]. The American College of Surgeons Committee on Trauma requires injury prevention and outreach activities to be conducted by Trauma Centers nationally [3]. This is covered in an entire chapter in their text *Resources for Optimal Care of the Injured Patient*. A trauma center's injury prevention program activities should be reflective of their trauma data results on mechanism of injury and targeted to local communities affected. Focusing on those injuries that occur most frequently is important, but a focus on those injuries that cause the most impact on the child, the most disability, to help reduce or eliminate those injuries is crucial as well. Pediatric surgeons can be critical in helping to get the message of injury prevention out to the public [3]. The American College of Surgeons notes that an effective injury prevention program has the following key elements [3]:

- Target the Community (know the injuries in the community)
- Work Upstream (identify the root causes of injuries and precipitating factors)
- Choose preexisting proven or promising programs (work with what works)
- Partner with other organizations (look regionally or nationally)
- Embrace the media (use the media to spread the message)
- Be politically savvy (work with governmental agencies)
- Do not forget the data (surveillance and monitoring is paramount)

Data can be obtained from many places including medical examiner's offices, state vital records, local and state law enforcement offices, and other governmental agencies. Recognizing the proximate cause of the injury including risk factors such as access to firearms, high risk behavior, use of alcohol or other illicit drugs is important in any injury prevention program. Trauma centers can also partner with regional and national organizations for prevention efforts. Pediatric trauma has multiple organizations that show regional or national efforts to study trauma and identify opportunities for injury prevention practices [7–9]. Injury prevention education should be presented both in person with interactive programs including education and activities. Safety messaging should be presented through the media and using social media outlets. During the COVID outbreak, many injury prevention messages had to be adapted for virtual presentations and through social media to reach the public.

Building upon this framework, Pressley et al. identified the ABDCE's of injury prevention. In their manuscript they note that “mechanisms of injury are rooted in a complex web of social, economic, environmental, criminal, and behavioral factors that necessitate a multifaceted, systematic injury prevention approach” [10]. They

describe a successful injury prevention program that began in a resource-limited neighborhood impacting an urban minority community. They utilized interventions that were aimed at changing both the community and home environments. Safe play areas were instituted as well as other home interventions. Utilizing a well-known mnemonic of trauma, the authors describe an Injury Coalition Free model of [10]

A—Analyze the data

B—Build a local coalition

C—Communicate the problem and raise awareness

D—Develop intervention and injury prevention activities

E—Evaluate the programs with ongoing surveillance

The results of this program are staggering. The initial programs focused on reducing several causes of injury for school-age children, such as motor vehicle pedestrian injury, assaults, firearms, and falls and was run out of Harlem Hospital in New York City. The interventions were a success with a decline, compared to pre-intervention rate, of 36% in traffic injuries, 45% in pedestrian injuries, 46% in violent injuries due to firearms and assaults. In 2001, Harlem had a 60% reduction in the overall injury rate in children. What is further remarkable is that the improvement in injury rates have been sustained with hospital admissions for children and adolescents under the age of 17 due to injury continuing to be 60% lower than pre-intervention rates [10]. These efforts have become national and have resulted in the Injury Free Coalition for Kids [9].

Adopting a plan for injury prevention education can make educational efforts easy. Focusing education based on seasonal activities that children and families engage in is very effective. In the spring, for example, children are getting outside again, so bike safety and helmet use are hot topics. Promoting correct helmet fit and use and a knowledge of bicycle traffic laws is important. Playground safety that includes supervision, safe equipment and surfaces is key. In 2019, a pedestrian was killed every 85 min resulting in over 6200 fatalities that year [11]. Pedestrian safety is important for school aged children who may not yet recognize the danger of crossing the road and the fact that a green light does not ensure that it is safe to cross the road. Pedestrian safety focuses on “looking left, right, and left again,” crossing at cross walks not mid street or between cars [12]. A community may need to evaluate their public safety plan to include signage and flashing lights in areas such as schools and parks where children spend more time. These efforts emphasize the injury prevention practices mentioned earlier in the chapter that look not only at the home or family involvement but also at community safety. Data showing that many pedestrian accidents occur in a specific area can be obtained from law enforcement and utilized with local government to place crosswalks or streetlights that can mitigate traffic accidents.

As summer approaches, water, pool, and boating safety become necessary to promote while continuing pedestrian and bike safety topics. More children aged 1–4 die from drowning than from any other cause except congenital birth defects [13]. Every year there are on average 3960 deaths due to unintentional drowning. While it would make sense that the highest rates of death occur in states in the southern part of the United States; Alaska, Oregon, Montana, Idaho, and Wyoming were 5 of

the top 12 states for drowning deaths between 2015 and 2019 [14]. Teaching children to swim is an essential parental responsibility. The American Red Cross and the YMCA are two community-based organizations that provide swimming classes [15, 16]. Utilizing lifejackets for all children on boats or near water is critical even for those that do not live near a water source. As families travel to vacation sites during the summer proper planning and education about the risks of summer activities are important to ensure safety. Fireworks and severe weather education such as lightening safety are also needed in the summer. According to the Consumer Product Safety Commission, there were 18 deaths due to fireworks in 2020. Furthermore, there was a 50% increase in deaths and injuries when compared to 2019 with 15,600 individuals treated in the emergency room due to firework related injuries. Children under 5 accounted for 11% of the total firework injuries [17].

In the winter, sledding, skiing, and ice-skating safety topics prevail along with winter travel safety. Messages such as “sledding feet first” and “ensuring safe runoff spaces for sledding” are essential. Proper clothing and safety equipment such as helmets are important to mitigate cold injury such as frostbite as well as traumatic injury. Home safety is important all year long with education on hot water temperatures, window safety guards, stair gates, crib and bed rails, safe storage of medications, cleaning solutions and other household items, and smoke and carbon monoxide detectors. Safe storage of firearms in the home is important for children of all ages. Gunshot wounds have an increasing prevalence in pediatric patients with nearly 1300 fatalities and 5790 nonfatal injuries annually [18]. Due to multiple factors including new purchases of firearms, financial strain, psychosocial stress and anxiety, the rate of firearm injuries increased during the recent COVID-19 pandemic [19]. Firearm violence is clearly an increasing public health issue nationally. In 2000, one in three homes with a child under 18 in the United States had a firearm [20]. The American Academy of Pediatrics states that the safest home for a child is one without guns. Mitigation strategies include ensuring proper storage of firearms at home safely with the firearm unloaded and stored separately from the ammunition. Lockboxes and gun safes can be acquired through commercial vendors [21].

Another topic essential all year long is car seat safety education. Since motor vehicle injuries are a leading cause of injury for children and teens, becoming familiar with some of the recommended car and booster seats for children and teen driving safety topics is key. Infants and toddlers should remain rear facing as long as possible, until the child outgrows their car seat’s maximum height and weight guidelines. Rear-facing is the safest. For older toddlers and preschool size children, use a forward-facing seat with 5-point harness for as long as possible, again up to the maximum size allowed by the seat. Booster seats for young school age children should be used to ensure proper position of the lap/shoulder belt systems until the child is 4 ft 9 in. tall, between age 8–12, and above 80 lb [22]. The rear seat is the safest for all children. Some general car seat safety is to never leave a child unattended in or around a vehicle, ensure the straps fit snugly and are correctly positioned, avoid wearing bulky winter coats under the car seat harness as it can affect the fit, and all children younger than age 13 are riding in the back seat. Involving a certified car seat technician to ensure child passenger safety by providing car seat education, checking car seat installation in a vehicle and fitting children in car seats

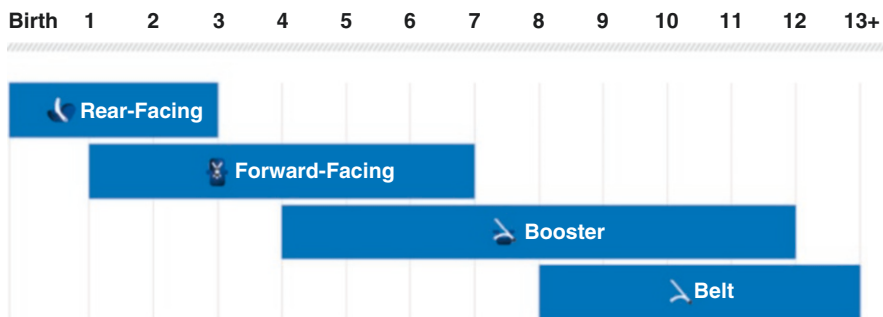


Fig. 2.2 Recommended car seats based on your child’s age and size. (Source: Car Seats and Booster Seats. National Highway Traffic Safety Administration. <https://www.nhtsa.gov/equipment/car-seats-and-booster-seats>, Accessed 26 Oct 2021)

Table 2.1 The 5-Step test for children to ride in a vehicle using a seat belt without needing a car seat or booster seat. (Adapted from: Take the 5-Step Seat Belt Fit Test. Safe Ride 4kids. <https://saferide4kids.com/blog/take-the-5-step-seat-belt-test/>, Accessed 26 Oct 2021)

	The 5-Step test for children to ride without a car seat or booster seat
1	Shoulder belt crosses over top of shoulder, not against neck
2	Child can sit with lower back against the vehicle seat back
3	The lap belt crosses the upper thighs against the hip bones, not the abdomen
4	Child can bend knees at end of seat while back is against seat back
5	Child can comfortably ride this way for entire ride

is beneficial [22]. Many local police, State Police and fire companies help to meet this need (Fig. 2.2). It cannot be emphasized enough, children are not ready to use a car seat belt restraint alone until they achieve a weight of 80 lb, a height of 4 ft 9 in., and age 8–12-years-old [1]. Car restraints are designed to fit adults, not children. Before allowing children to ride in a car with only a seat belt, they should be able to pass the 5-step-test annotated in Table 2.1.

Ensuring teens are safe and capable drivers is an important task as they become more independent. In 2019, there were a reported 2042 individuals killed in motor vehicle collisions involving drivers between the ages of 15 and 18 years [23]. All 50 states and the District of Columbia have instituted graduated driver license systems that provide for periods of supervised driving prior to the ability to be a fully licensed driver. These systems can reduce a teen drivers’ risk of being involved in a motor vehicle collision by 50% [23]. Information about specific state requirements for licensing of teenage drivers can be found at <https://www.ghsa.org/state-laws/issues/teen%20and%20novice%20drivers>. Distracted driving is an important topic to discuss with all drivers due to the competing interests of a cellphone or other electronic device and friends in the car. In 2017, 8% of teen (15–19) drivers who were involved in fatal crashes were distracted at the time of the crashes [24]. Seat belt usage is lowest amongst teen drivers. Forty-five percent of teen drivers who died from a motor vehicle collision in 2019 were not wearing a seat belt. Speeding is also a significant risk factor for motor vehicle collisions involving teen drivers.

Speeding was a factor in 27% of fatal crashes involving teen drivers in 2019 [23]. Empowering parents to serve as role models is an important part of injury prevention regarding teen driving. Ensuring parents model safe driving techniques including not speeding, wearing seatbelts, and avoiding other risky behavior or distracted driving can have a positive influence on teens [23].

Nationally, “falls” within the age range of 0–24 cause the highest number of injuries at nearly 29%, followed by “struck by or against” as the second leading mechanism of injury [25]. Every day, approximately 8000 children are seen in United States emergency rooms after having suffered a fall, affecting approximately 2.8 million children yearly [25]. In the pediatric population, instituting fall prevention programs is challenging because of the varied ways children fall. Developmentally we expect young children to fall while learning to walk and run, but it’s all the other ways children fall that becomes the challenge. Children fall off bicycles and monkey bars, fall on and off trampolines, riding a scooter, and fall out of shopping carts and off horses. All fall prevention education should be geared toward the developmental level of the child. Looking at your local trauma center data and the surrounding communities should direct your injury prevention program activities. Community involvement is important to ensure proper playground equipment and age-appropriate equipment based upon the community needs. Having safe spaces that are well maintained can help to mitigate unintentional injuries.

As noted earlier in the chapter, when looking at injury prevention we often focus on the most common causes of injury in the community being served, but it is essential also to look at contributing factors as well. These precipitating factors are important to understand to ensure appropriate mitigation practices and injury prevention opportunities. Drugs, alcohol, behavioral and mental health issues, violence, poverty, and several other factors may be involved in poor childhood safety. An inability to afford cabinet or window locks can have a big impact on child safety during the toddler and preschool years. Acquiring grant funds to provide low cost or free resources to families is very beneficial. Several children’s hospitals nationally host safety stores to provide low-cost items that underscore their safety and injury prevention efforts.

Conclusions and Take Home Points

Injury prevention is an important part of any pediatric trauma program. Recognizing the fact that most pediatric traumatic injuries can be prevented either with home or community safety measures allows one to focus on interventions that can reduce the morbidity and mortality of trauma. These efforts should not be done in a silo but instead should focus on collaboration with civic leaders, governmental agencies, community-based organizations, and neighborhood coalitions. Partnerships with regional and national organizations can also provide opportunities and additional resources to develop local programs. Utilizing an injury prevention framework such as the ABCDE framework mentioned earlier in the chapter can help to develop a

needs assessment as well as appropriate interventions that will be successful in the community. Data acquisition, surveillance and monitoring are important steps to ensure the continued success of an injury prevention program.

- Knowledge of common injuries within a community as well as the root causes and precipitating factors are the cornerstones of any injury prevention program.
- Successful injury prevention programs utilize interventions that are aimed at changing both the community and home environments.
- Surveillance and monitoring of injury prevention programs are paramount to ensure ongoing success and continued improvement.
- Partnerships with regional and national organizations such as the Injury Free Coalition for Kids (<https://www.injuryfree.org/index.cfm>) can provide additional resources for any intervention program.

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Chapter 3

Trauma Systems and Pediatric Trauma Centers



Pamela M. Choi and Matthew D. Tadlock

Abstract Trauma is the most common cause of mortality in children. While adult trauma care has been well established, the pediatric population represents a distinct and broad spectrum of patients with unique anatomic, physiologic, and psychologic characteristics, particularly in response in to injury. Not every child has the ability to be near a pediatric trauma center; therefore a mature trauma system with strategically placed pediatric trauma centers that can support the injured child is crucial to the community and provides the best opportunity for treatment, survival, and recovery.

Keywords Trauma system · Pediatric trauma center · Prehospital care · Verification · American College of Surgeons

History of the Trauma System

The evolution of the modern trauma system began in the 1960s with the development of state trauma systems along with funding for emergency medical service systems and trauma prevention in the National Highway Safety Act of 1966 and the Emergency Medical Services Systems Act of 1973 [1]. Coordinated trauma care became possible as communication and transportation systems between prehospital care and hospitals became more refined. The American College of Surgeons (ACS) formed the Committee of Trauma and in 1976 and subsequently published the first edition of *Optimal Hospital Resources for Care of the Seriously Injured*, which has undergone several updates and provides the criteria needed for trauma systems and

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trauma centers. The ACS also developed the Advanced Trauma Life Support (ATLS) course in 1979 to standardize trauma care [2].

Because 25% of all traumatic injuries are in children, the need for pediatric-specific trauma care was identified, followed by the development of pediatric trauma centers/systems that evolved from the models set by adult trauma care [2]. Pediatric trauma centers were first established in the 1970s, and a section on pediatric trauma was added to the ATLS course in 1983. The Emergency Medical Services for Children program was established in 1984 by the Department of Health and Human Services and the National Highway Traffic Safety Administration (NHTSA). In addition to state designation as a pediatric trauma center, the ACS also offers an additional separate verification process for pediatric programs.

Overview of the Trauma System

Trauma remains the most common cause of mortality in children; therefore, the impact of a pediatric trauma system is significant [3, 4]. Furthermore, approximately 17.4 million children live outside a 60-min range of a pediatric trauma center [5, 6], and an estimated 28% of children live in counties with no trauma center [7]. Thus, it is incumbent upon the trauma system as a whole to effectively triage, transport, and treat the injured pediatric patient within their geographic region.

The trauma center is not an isolated entity but rather the core of the trauma system. Any pediatric trauma center must fill this role and have the necessary resources to care for injured children. The trauma center is the leader in developing the infrastructure required of a successful trauma program and is responsible for coordinating of resources throughout the entire care continuum, including prehospital care and rehabilitation (Fig. 3.1) [8]. This includes active participation in prehospital trauma training, developing and linking field triage criteria to trauma team activation procedures, providing medical oversight, and developing treatment protocols [2]. The trauma center must also be engaged in quality assurance/process improvement endeavors, research, advocacy, outreach, and injury prevention programs [2, 8].

To be a pediatric trauma center, state designation is first required and is determined by state or regional criteria. Pediatric trauma center verification is an evaluation process conducted by the American College of Surgeons (ACS). Not all designated trauma centers are ACS verified. Criteria for designation may vary from state to state or region to region, while the criteria for ACS verification are standardized.

The importance of pediatric trauma centers has been demonstrated throughout the literature. Quite simply, injured children have better outcomes when treated at a pediatric trauma center. This includes decreased overall mortality and improved functional outcomes [7, 10–16]. These superior outcomes in pediatric trauma centers have persisted across different mechanisms, ages, and quality metrics.

Byrne et al. utilized the NHTSA Fatality Analysis Reporting System and found that counties with pediatric trauma centers had decreased motor vehicle crash (MVC) mortality in children <15 years old [7]. Similarly, a National Trauma Data

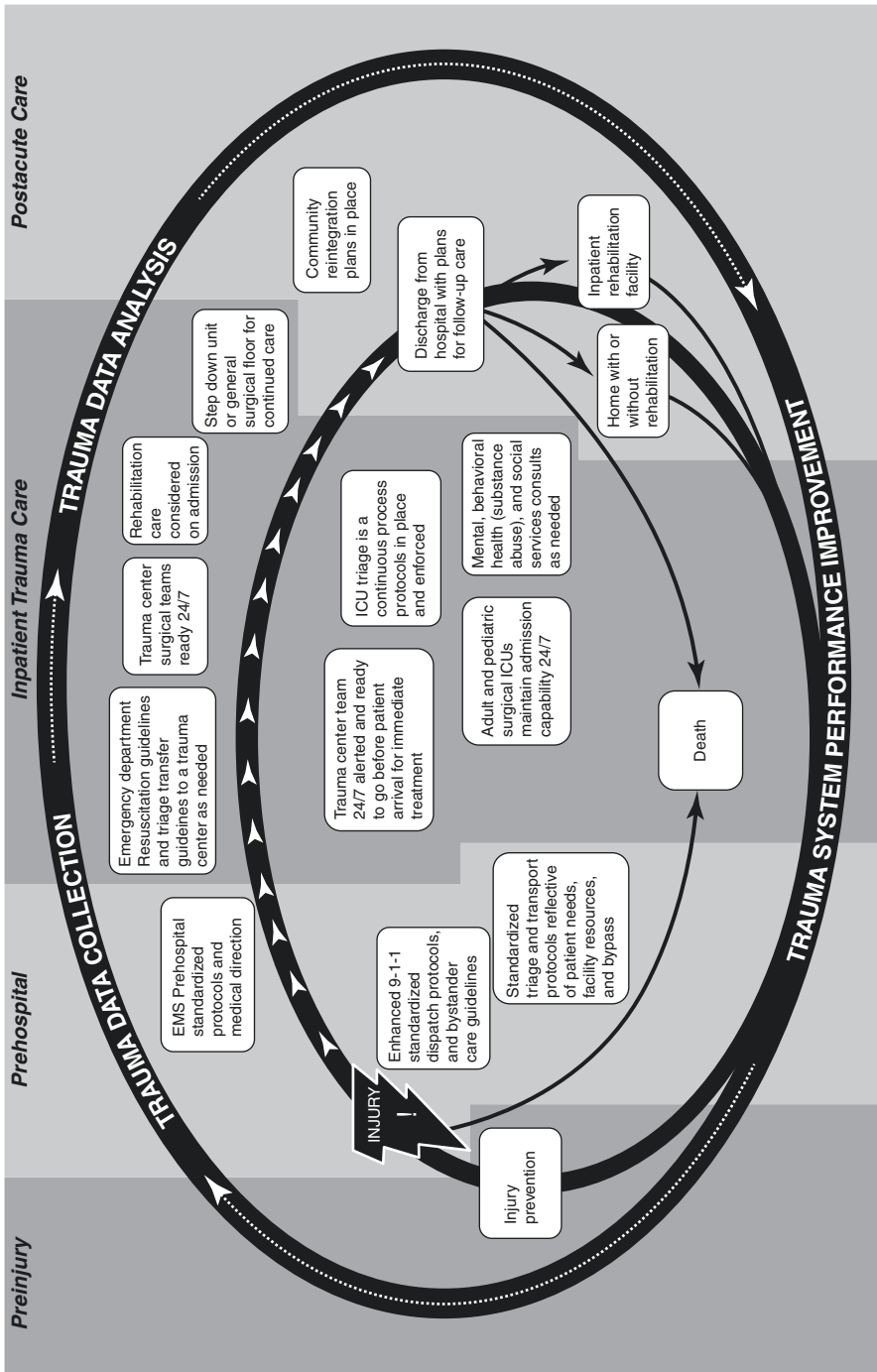


Fig. 3.1 Complex and integrated trauma care curriculum [9]

Bank (NTDB) study also found that children <15 years injured by MVC and treated at an adult trauma center had an increased incidence of pneumonia [17]. The same study also found that pediatric patients (0–17 years) had an increased odds of a laparotomy when treated at an adult trauma center [17].

It had been theorized that adolescents, being much closer to adult size and physiology, would have equivalent outcomes at adult trauma centers. However, this is not true. Instead, adolescents treated at adult trauma centers had increased mortality when compared to pediatric trauma centers [16, 17]. Severely injured adolescents (15–19 years, Injury Severity Score (ISS) >25) also had increased length of stay, lower home discharge rates, increased imaging, and increased invasive procedures at adult trauma centers compared to those treated at pediatric trauma centers [18]. Furthermore, when cared for at pediatric trauma centers, adolescents (15–18 years) with penetrating injuries also had decreased operative interventions and decreased mortality [19].

Nonoperative management of blunt solid organ injuries has become the standard of care in pediatric trauma; therefore, rates of operative intervention have become a quality metric. Adult trauma centers have higher rates of operative intervention in children than pediatric trauma centers [20–23]. Several NTDB studies have found that adult trauma centers had an increased likelihood of splenectomy for blunt splenic injury in pediatric patients [23, 24]. Rates of angioembolization for blunt splenic injury were also higher at adult trauma centers without any improvement of outcomes [21, 25].

Computed tomography (CT) can be an essential diagnostic tool in evaluating the injured patient; however, minimizing radiation exposure in pediatric patients whenever possible is also important. In one study, not only were patients with pelvic fractures treated at pediatric trauma centers found to have a decreased complication rate, but CT scan utilization was also reduced [26]. In general pediatric trauma centers have lower rates of CT scan utilization [26–28], and when CT scans are conducted, children are exposed to lower doses of radiation [29, 30].

Prehospital Trauma Care

The importance of the entire trauma system cannot be understated. Often, this begins with prehospital trauma care that is organized, timely and standardized. It is not economically nor practically feasible to have a Level-I pediatric trauma center within 60 min of every child in the country. Therefore, a structured system must be developed to guide prehospital personnel to transport “the right child to the right hospital at the right time”—a mantra for all emergency medical services.

Prehospital care encompasses dispatch systems, communications with hospitals, as well as medical care and transportation from the scene to the hospital [8]. The Emergency Medical Services for Children (EMS-C) program was created in 1984 to optimize prehospital care for ill/injured children. Pediatric trauma centers often develop prehospital care education, protocols, and guidelines for pediatric trauma triage [31–33]. A joint policy statement from the American Academy of Pediatrics,

American College of Emergency Physicians, Emergency Nurses Association, National Association of Emergency Medical Services Physicians, and National Association of Emergency Medical Technicians has also outlined multiple recommendations for pediatric readiness for emergency medical services systems (Table 3.1) [34].

Table 3.1 Pediatric readiness in emergency medical services systems [34]

Include pediatric considerations in EMS planning and the development of pediatric EMS dispatch protocols, operations, and physician oversight (for example, as outlined in the National Association of Emergency Medical Services Physicians position statement “Physician Oversight of Pediatric Care in Emergency Medical Services”)
Collaborate with medical professionals with significant experience or expertise in pediatric emergency care, public health experts, and family advocates for the development and improvement of EMS operations, treatment guidelines, and performance-improvement initiatives
Integrate evidence-based, pediatric-specific elements into the direct and indirect medical oversight that constitute the global EMS oversight structure
Have pediatric-specific equipment and supplies available, using national consensus recommendations as a guide, and verify that EMS providers are competent in using them
Develop processes for delivering comprehensive, ongoing, pediatric-specific education and evaluating pediatric-specific psychomotor and cognitive competencies of EMS providers
Promote education and awareness among EMS providers about the unique physical characteristics, physiologic responses, and psychosocial needs of children with an illness or injury
Implement practices to reduce pediatric medication errors
Include pediatric-specific measures in periodic performance-improvement practices that address morbidity and mortality
Submit data to a statewide database that is compliant with the most recent version of the National Emergency Medical Services Information System and work with hospitals to which it transports patients to track pediatric patient-centered outcomes across the continuum of care
Develop, maintain, and locally enforce policies for the safe transport of children in emergency vehicles
Develop protocols for the destination of pediatric patients, with consideration of regional resources and weighing of the risks and benefits of keeping children in their own communities
Collaborate, along with receiving emergency departments, to provide pediatric readiness across the care continuum
Include provisions for caring for children and families in emergency preparedness planning and exercises, including the care and tracking of unaccompanied children and timely family reunification in the event of disasters
Promote overall patient- and family-centered care, which includes using lay terms to communicate with patients and families, having methods for accessing language services to communicate with non-English-speaking patients and family members, narrating actions, and alerting patients and caregivers before interventions are performed. In addition, allow family members to remain close to their children during resuscitation activities and to practice cultural or religious customs as long as they do not interfere with patient care
Have policies and procedures in place to allow a family member or guardian to accompany a pediatric patient during transport when appropriate and feasible
Consider using resources compiled by the Emergency Medical Services for Children program when implementing the recommendations noted here