

Pediatric Trauma

Pathophysiology, Diagnosis,
and Treatment

SECOND EDITION



Edited by

David E. Wesson • Bindi Naik-Mathuria

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Pediatric Trauma



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SECOND EDITION**

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Preface

Injury continues to be the leading cause of death and disability in children older than one year in the United States and in older children and adolescents worldwide. The spectrum of causes varies with age, but blunt forces cause the overwhelming majority of injuries. The common adage “children are not just small adults” certainly holds true in pediatric trauma, as many of the differences in behavior, risk, exposure, anatomy, and physiology between children and adults have a direct bearing on trauma care. In recent years, this reality has been widely accepted in the field. The Committee on Trauma of the American College of Surgeons has specifically addressed the needs of injured children in its resources document and in the curriculum of its Advanced Trauma Life Support® course. In many countries around the world, children’s hospitals, pediatric surgical subspecialists, pediatric emergency physicians, and prehospital providers have focused on the needs of injured children and have established pediatric-specific benchmarks in the management of trauma care. But there is a problem. There are simply not enough children’s hospitals or pediatric trauma specialists to meet the needs of all the injured children. Much, if not most, of pediatric trauma care is provided in general hospitals by nonpediatric specialists.

This book is intended for everyone who treats injured children. The primary target audience includes pediatric surgeons, general surgeons, trauma surgeons, emergency physicians, and surgical subspecialists. Trainees and

mid-level providers in any of these fields, as well as providers in low-resource countries, may also find this book useful as it provides a broad overview of the key topics in pediatric trauma care. The content not only relates primarily to direct patient care, but also includes topics such as disaster planning, injury prevention, and long-term outcomes.

The book is divided into four parts. **Part I** deals with trauma systems for children, including epidemiology and organization of pediatric trauma care. **Part II** covers general principles of resuscitation and supportive care relevant to all pediatric trauma patients, including management of burns and child abuse, and pediatric-specific imaging and transfusion recommendations. **Part III** covers the management of specific injuries, including brain, truncal, skeletal, and vascular injuries. Finally, **Part IV** deals with outcomes, rehabilitation, and effective communication with families of injured children. The chapters from the first edition have been revised and updated to reflect the most contemporary practices within the field.

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David E. Wesson and Bindi Naik-Mathuria



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Trauma systems for children

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Epidemiology of pediatric trauma

DAVID E. WESSON

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Introduction

Epidemiology is the study of the distribution of diseases in groups or populations. One of its aims is to define the occurrence of disease by place and time in the general population and in specific subpopulations. The overarching goal is to reduce the incidence and severity of specific diseases. Injury epidemiology involves the collection of data on the time, place, mechanism, and victim of injury. Studies of pediatric injury epidemiology have had a major impact on our understanding of pediatric trauma. Injury epidemiology has allowed us to identify and quantify specific injury risks, develop prevention and treatment strategies, and monitor their effectiveness. The study of injury epidemiology has produced one fundamental fact: Injuries are the leading threat to the health and well-being of young people in our society today [1,2]. This is of major importance to public health officials and health care providers alike.

Epidemiology can help clinicians by identifying common causes, mechanisms, and patterns of injury. This is best done in defined populations of children at the local, regional, national, or international level. Epidemiology tells us that motor vehicle crashes and falls from a great height cause more life-threatening injuries than sports and recreational activities. We know that blunt injuries far outnumber penetrating injuries and that children are prone to develop intracranial hypertension from cerebral edema after a closed head injury. The astute trauma surgeon will learn to suspect and recognize these patterns based on the age of the child and the mechanism of injury. As in most areas of surgical practice, the history of events before presentation aids significantly in diagnosis and treatment.

Historical perspective

One hundred years ago, infections were the great scourge of children in our society. Today the problem is injury or trauma. Changing social conditions, better housing and nutrition, immunization, and quarantine of infectious cases all helped reduce the threat from infectious diseases. Over the same time period, new environmental factors, notably the introduction of the automobile, increased the risk of injury.

Trauma systems for children

Our present understanding of the epidemiology of trauma in our society began in the 1960s with the publication of a monograph entitled *Accidental Death and Disability: The Neglected Disease of Modern Society* by the Committees on Trauma and Shock of the National Academy of Sciences [3]. This report pointed out that accidental injuries were the nation's most important environmental health problem. This was followed by another important publication *Injury in America* that documented in much greater detail the impact of injuries on American society and suggested a broad approach to the problem encompassing epidemiology, prevention, biomechanics, acute treatment, and rehabilitation [4].

Since these two important publications appeared, much progress has been made both in prevention and treatment of injuries. During the 1980s and 1990s, the mortality rate from pediatric trauma in the United States fell by about 50%. This trend has continued. The mortality rate from unintentional injuries among children 1–19 years of age in the United States fell from 15.0 per 100,000 in 2000 to 8.3 per

100,000 in 2013 [1,2]. No doubt this resulted from improvements in both prevention and treatment. But there are many reasons why we will have to increase our prevention efforts if we hope to see another 50% reduction in the next 20 years.

The costs of treating trauma victims and the pain and suffering they endure are very high, even when the final outcome is excellent. Prevention would eliminate these effects. About 50% of pediatric trauma deaths occur in the field before the victim even reaches a trauma center. Here too, prevention is the answer. Most trauma systems now have very low preventable death rates. There is always room for improvement, but the curve is flattening out. It is unlikely that substantial reductions in the overall trauma mortality rate in the United States could be achieved by better care of the injured.

We lack effective treatments for primary brain injuries, the most common cause of death in pediatric trauma. Here too, prevention is the solution. A report from the National Pediatric Trauma Registry showed that about 70% of pediatric injury deaths are caused by central nervous system (CNS) injury [5]. Only prevention can significantly reduce these deaths.

Injury facts

More than half of all childhood deaths in the United States result from injuries. In 2013, among children 1–19 years old, unintentional injuries (accidents), suicide (self-harm), and homicide (assault) were the first, second, and third leading causes of death, respectively [1]. Together they account for >56% of all deaths among children 1–19 years of age. Unintentional injuries are the number one childhood killer in all age brackets—1–4, 5–9, 10–14, and 15–19 [1]. In 2013, unintentional injuries of all types, including suffocation, drowning, burns and scalds, as well as blunt and penetrating trauma, caused 6489 deaths among children 1–19 years of age in the United States. This represents 34% of all pediatric deaths and a mortality rate of 8.3 injury deaths per 100,000 per year. There has been considerable improvement in these numbers since 2000. In that year, there were 11,232 deaths accounting for 44% of all deaths at a rate of 15.0 per 100,000 children from 1 to 19 years of age [2].

Also in 2013 suicide, the second leading cause of death, resulted in 2143 deaths or 11% overall. Homicide contributed 2021, also around 11% of all deaths. The incidence of homicide plotted against age creates a U-shaped curve with peaks among infants and adolescents. Among infants, the most common mechanism is abusive head trauma (AHT) or “shaken baby syndrome” that peaks at 2–3 months of age. This is the age at which colic is most prevalent suggesting that infant crying may trigger at least some cases of AHT. At our Level I pediatric trauma center, we admit 60–80 children each year with injuries caused by physical abuse. Most of them are infants less than 6 months of age. Child abuse accounts for more than one-third of all trauma deaths at our center. It is the single most common cause of fatal injury.

In Texas, injuries are the leading cause of death among children from 1 to 17 [6]. Motor vehicle–related injuries are the most common cause. Most were passengers, followed by

pedestrians struck by a motor vehicle and drivers. In Texas, almost two-thirds of pediatric homicides are committed with a firearm, usually a handgun. Gunshot wounds are also the most common mechanism of child suicide.

For every injured child who dies dozens more are hospitalized and hundreds are treated in emergency centers.

Risk factors

The risk of most types of injury varies with age. Homicide is the leading cause of injury death for infants from 1 month to 1 year of age in the United States. The homicide rate for boys is almost three times higher than for girls. It is also much higher among African Americans than Caucasians. Child abuse causes the majority of homicides in the first year of life; gunshot wounds predominate among teenagers. A person known to the victim, most commonly a parent, perpetrates the vast majority of homicides.

Suffocation is the number one cause of unintentional injury death in infants, but is rare in other groups. Drowning and submersion are the leading cause of death in children 1–4 years of age. Toddlers have a much higher death rate for burns and scalds than older children do. The risk of injury for school-aged boys is far greater than for girls. Motor vehicle occupant injuries predominate among teenagers 15–19 years old.

The likelihood of a child being fatally injured is associated with single parentage, low maternal education, young maternal age at birth, poor housing, large family size, and parental abuse of alcohol and other drugs. A study from Newcastle, England, of fatal head injuries revealed that children from poorer neighborhoods were at greater risk than were those from more affluent areas [7]. The authors concluded that the lack of proper playgrounds, which forced poor children to play in the streets, accounted for the difference. Children living in trailer homes in the United States have twice the risk of dying in house fires than children living in other types of housing. Children who live in rural counties have a higher incidence of motor vehicle–related injury and a higher risk of dying compared to urban children. There is also a strong correlation between per capita income and mortality from motor vehicle crashes among all the counties in the lower 48 states. Racial and ethnic factors correlate with other socioeconomic determinants, but even when these are controlled for, American Indians have the highest rates of injury mortality in the country.

Costs

It is difficult to accurately determine all of the costs of pediatric trauma but it is clear that injuries are the leading cause of medical costs. Most estimates suggest that these costs are enormous. Hospital costs represent only one slice of the pie. Other costs include medical services, lost productivity, indirect costs to families for lost income, and so on. Rice and Mackenzie estimate that the cost of injury to children from birth to 14 years of age in the United States in 1985 was \$13.8 billion [8]. A recent report entitled “Unintentional Injuries in Childhood” in the Future of Children series published by

the David and Lucile Packard Foundation provides a lot of data on this subject [9]:

- For school-aged children and teenagers, injuries are almost as frequent as the common cold.
- In 1996, injuries—mostly to the brain, spinal cord, and limbs—and burns left an estimated 150,000 children permanently disabled.
- Injuries to children resulted in the loss of 2.7 million quality adjusted life years.

This publication also attempted to express the impact of childhood injuries in financial terms. It estimated the total financial burden of childhood injury in America for 1996 as \$81 billion:

- Direct spending for medical services over the lifetime of the victim amounted to \$14 billion.
- Other resource costs including emergency medical services totaled \$1 billion.
- Lifetime productivity losses amounted to \$66 billion.

Trends

We have made substantial progress in the fight against childhood injury. The death rate has declined significantly in one generation. Unintentional injury mortality fell by 50% from 1970 to 1995 in the Organization for Economic Cooperation and Development (OECD) nations (the 26 richest nations in the world) [10]. During the same period, the proportion of all childhood deaths caused by injuries rose from 25% to 37%.

Improved highway and vehicle design, smoke detectors and alarms, car seats, and seat belts have all played a part in reducing childhood injury mortality. Even the homicide rate has declined. This trend continues [1,2].

In the province of Ontario, Canada, the number of children seriously injured while bicycling fell sharply during the 1990s [11]. This was due in part to legislation making helmets mandatory for children riding a bicycle on public roads. Across Canada, there is a clear association between bike helmet legislation and the risk of head injury. Provinces with helmet laws had a 25% lower head injury risk.

Comparisons with other countries

Injuries are the principal cause of death for children 1–14 years of age in all nations in the OECD, the wealthiest countries [10]. Injuries account for 40% of all deaths in children 1–14 years of age. Together they take the lives of more than 20,000 children each year in the OECD nations. Traffic accidents account for 41% of the deaths. For every death, there are 160 hospital admissions and 2000 emergency department visits. Injuries account for almost 30% of the total burden of childhood disease measured by disability adjusted life years.

The Swedish, British, Italian, and Dutch child injury death rates are among the lowest; the United States rate

is among the highest along with Poland, New Zealand, Portugal, and Mexico. The United States accounts for almost one-third of all child injury deaths in the developed nations. More than 12,000 child injury deaths a year could be prevented if all countries had the same child injury death rate as Sweden. Bringing the United States rate down to that of Sweden would save 4700 American children each year.

Common clinical scenarios and patterns of injury

Astute clinicians learn to recognize common clinical scenarios and patterns of injury. Thus, knowledge of the circumstances can help identify patients with certain types of injury. For example, restrained children in side-impact crashes are much more likely to sustain injuries from compartment intrusion than children in frontal crashes. Side-impact crashes also cause more severe injuries (Injury Severity Score >15; Glasgow Coma Scale <9) and more injuries to the head, cervical spine, and chest to restrained children [11]. In contrast to this, restrained children in frontal crashes are more likely to suffer injuries to the abdomen and lumbar spine.

The following is a partial list of common pediatric trauma clinical scenarios:

- The infant brought in with a vague history (e.g., a fall at home), altered mental status, and severe neurotrauma from child abuse
- The properly restrained toddler involved in a high-speed motor vehicle crash brought in by ambulance who proves to have no significant injury
- The school-aged child struck by a motor vehicle who presents with a lower limb fracture, intra-abdominal or thoracic visceral trauma, and a closed head injury
- The preteen who suffers a high-grade hepatic or splenic injury from an off-road all-terrain vehicle (ATV) crash
- The child with an acute epidural hematoma following a seemingly minor direct blow to the head
- The rear seat passenger with a transverse abdominal bruise and occult small bowel and lumbar spine and/or spinal cord injuries from a lap belt
- The child with a duodenal hematoma or pancreatic laceration from a direct blow to the abdomen from a hockey stick or bike handlebar

Emergency physicians and trauma surgeons should be on the alert for children with these typical clinical presentations.

Role of the trauma center

The primary role of the trauma center is, of course, to care for patients with life- and limb-threatening injuries. Trauma centers can also make important contributions to injury control through education and prevention. Education efforts can target health care providers and the

greater community. Education is a necessary component of all injury prevention programs and is usually a necessary first step before new legislation mandating injury prevention measures such as seat belts, child restraints, bike helmets, and so on. Trauma centers can also help identify specific causes of injury and associations or patterns of injury. Data from the trauma registry showing a significant number of fatal bicycling injuries motivated the trauma program staff at the Hospital for Sick Children, Toronto, to start a bike helmet campaign. The first phase of the campaign was intended to educate the public, health care workers, government officials, and politicians of the risk of bike-related head trauma and of the benefits of bike helmets. This eventually led to a bike helmet law in the province of Ontario, which contributed significantly to a 26% reduction in bicycling-related head injuries among children 1–19 years of age [12]. The rate of fatal injuries ultimately fell by more than 50% [13]. A national population-based study across Canada confirmed that parts of the country with helmet laws had lower head injury rates.

SUMMARY

Injuries are the leading risk to the lives and limbs of children from infancy through adolescence in our modern world. The mechanisms and the numbers vary with age, gender, race, parental education, social class, and economic status. Awareness of these variations can assist clinicians in the management of pediatric trauma victims. Analysis of these variations can also help us develop ways of preventing childhood injuries from occurring in the first place.

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Organizing the community for pediatric trauma

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Introduction

Modern pediatric trauma care, like adult trauma care, has undergone constant evolution during the past generation, since the care of injured children first emerged as a distinct discipline. In part, this was driven by the widespread recognition among pediatric surgeons—initially led by Dr. Jacob Alexander Haller, Jr., of The Johns Hopkins University in Baltimore—that pediatric trauma care constituted a key component of the subspecialty of pediatric surgery [1], and in part by the ultimate recognition by the Federal government that emergency medical services (EMS) for children had been neglected during the development of EMS systems nationwide [2]. Since their inception, pediatric trauma programs have stressed the need for full integration with their affiliated adult trauma programs and their regional EMS systems, to ensure seamless care and cost-effective use of scarce human and financial resources [3]. They have also recognized the need for all who care for pediatric patients to ensure that the special needs of injured children are met at every level of trauma and EMS system organization [4].

To this end, this chapter describes the current state of the art with respect to pediatric trauma system design. Consistent with this purpose, the public health approach to trauma and EMS systems will be emphasized. Additionally, the literature supporting the need for and components of pediatric-capable trauma and EMS systems will be reviewed. Finally, critical elements of prehospital care for the pediatric trauma patient will be delineated, to a r m n o t o n l y

pediatric-capable trauma professionals, but also adult-oriented trauma professionals—who, of necessity, provide the majority of pediatric trauma care in the United States—with a working knowledge of pediatric trauma system design and function, to ensure, insofar as is possible, that every child in every community has the benefit of optimal pediatric trauma prevention and treatment, hence the greatest possible opportunity for relief, recovery, and rehabilitation.

Trauma and EMS for children (EMSC)

Modern EMS systems evolved because of the recognition that trauma and sudden cardiac emergencies were the leading causes of death in the United States, and that the largely volunteer, à r e c o m p a n y - b a s e d r e s c u e s q u a d s t h a t h i s t o r i c a l l y c o m p r i s e d m o s t E M S w e r e n o t o p t i m a l l y p r e p a r e d t o m e e t t h i s c h a l l e n g e . T h e p h y s i c i a n s w h o f i r s t c r e a t e d t h e E M S s y s t e m s w e r e t r a i n e d c h i e f l y i n t h e a d u l t - o r i e n t e d s p e c i a l t i e s o f s u r g e r y , i n t e r n a l m e d i c i n e , c a r d i o l o g y , a n d a n e s t h e s i o l o g y [5] . I n f a n t s a n d c h i l d r e n w e r e c a r e d f o r i n t h e s e E M S s y s t e m s , b u t t h e i r n e e d s w e r e n o t s p e c i a l l y a d d r e s s e d , a n d d e f i c i e n c i e s i n t h e i r c a r e w e r e n o t r e c o g n i z e d , b a s e d o n t h e f a l s e n o t i o n t h a t c h i l d r e n c o u l d b e t r e a t e d a s l i t t l e a d u l t s . H e n c e , n o n e o f t h e k e y l e g i s l a t i v e i n i t i a t i v e s t h a t r e s u l t e d i n t h e c r e a t i o n o f m o d e r n E M S — t h e H i g h w a y S a f e t y A c t o f 1 9 6 6 , t h e E m e r g e n c y M e d i c a l S e r v i c e S y s t e m s A c t o f 1 9 7 3 , a n d t h e P r e v e n t i v e H e a l t h a n d H e a l t h S e r v i c e s B l o c k G r a n t P r o g r a m o f 1 9 8 2 t h a t u l t i m a t e l y r e p l a c e d t h e E M S S y s t e m s A c t — m a d e s p e c i a l m e n t i o n o f t h e u n i q u e n e e d s o f i n f a n t s