



## Pediatric Surgery

## Pediatric firearm injuries: Anatomy of an epidemic



Gun violence is the second the leading cause of mortality in pediatric trauma, with only motor vehicle collisions responsible for more pediatric deaths.<sup>1–3</sup> Despite increasing rates of vehicle miles traveled each year, increased safety efforts have substantially decreased deaths attributable to motor vehicle accidents. In contrast, the number of pediatric firearm injuries has continued to increase (Fig 1).<sup>3,4</sup> In 2019, firearms resulted in the deaths of more than 1,300 infants and children, alongside thousands more surviving with devastating and serious life-altering injuries.<sup>1,2</sup> These injuries continue to be a very worrisome public health issue because they are more fatal than any other injury presenting to trauma centers (Fig 2). Pediatric firearm deaths are tragedies that should certainly be preventable, although effective solutions remain elusive. Contributing to the failure to decrease firearm-related mortality are fundamental gaps in existing information, which prevent an accurate description of this problem.

## Literature Search

Research describing the pattern of firearm injury in the pediatric population is rare. Recently, there have been several adult studies examining injury patterns, using autopsy analyses from victims of combat scenarios or civilian, public mass shootings (CPMS).<sup>5–8</sup> Epidemiologic studies describing pediatric firearm injuries have also been published.<sup>2,9,10</sup> However, the variations in anatomic

patterns of pediatric firearm injury, which are key to improving care and prevention, have yet to be described. Here we present selected data characterizing firearm injury in the pediatric US population during the past 7 years from which we hypothesize that the firearm injury and mortality risk differs among infants, adolescents, and adults. We offer several observations that may provide guidance for future research and action.

The National Trauma Data Bank provides encounter-specific information from more than 900 trauma centers in the United States and includes both pediatric and adult patients. Throughout a 7-year time frame (2010–2016), we extracted data after approval by the institutional review board of the University of Pennsylvania (Philadelphia, PA) for all patients aged 0 to 19 years with firearm-related injuries. These data included the following 5 mechanisms of firearm injury: assaults, unintentional injuries, suicides, legal intervention (ie, firearm injury incurred from a law enforcement officer in the line of duty), and undetermined use, all classified by diagnosis codes of external injury (*International Classification of Disease, Clinical Modification, 9th and 10th revisions*). We then used the Abbreviated Injury Scale to identify body region and severity of injury. There were 36,581 encounters for pediatric firearm injuries in 7 years, including 4,017 deaths, corresponding to a case fatality rate of 11.0%. Assaults accounted for the majority of cases ( $n = 29,036$ , 79.4%). Fewer encounters occurred in children  $\leq 14$  years of age (12.8%), and more than half (50.4%) occurred in the subset

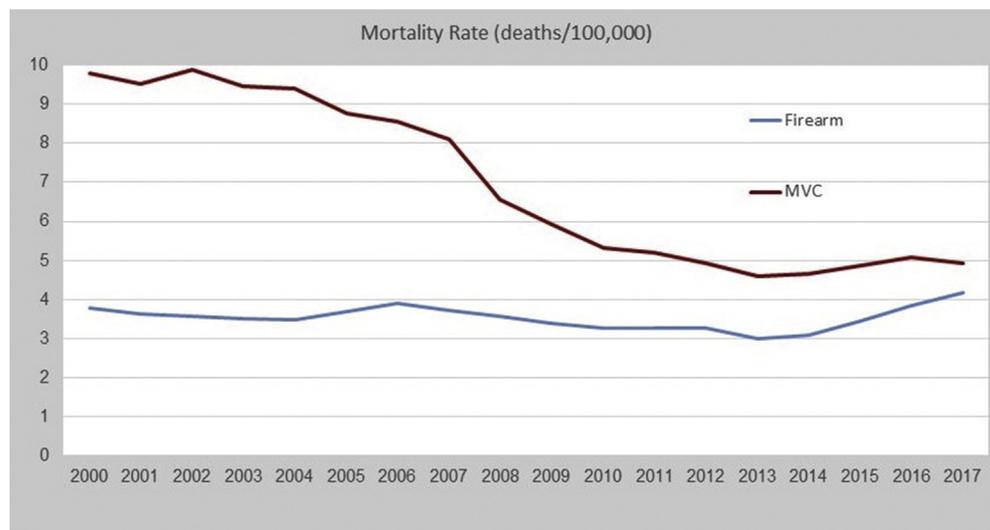
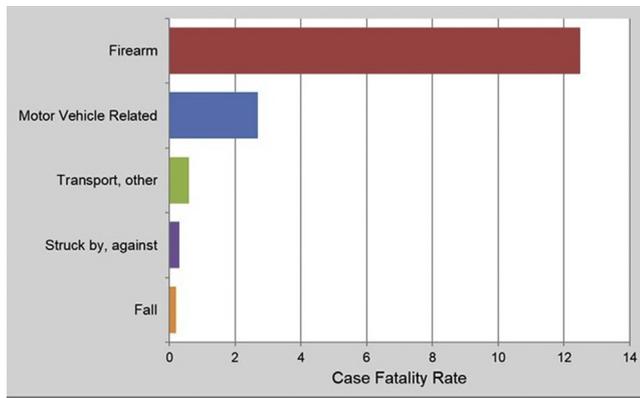


Fig 1. Motor vehicle collision deaths have decreased substantially during the past 20 years in contrast to a stable rate of firearm-related mortality.



**Fig 2.** Case fatality rate is the greatest among firearm-related injuries in the pediatric population. Data were abstracted from the National Trauma Data Bank.

of those ages 18 and 19 years old. The Table and Figure 3 report mortality data categorized by pediatric subgroups according to mortality tables of the Centers for Disease Control (<1, 1–4, 5–9, 10–14, 15–19 y), combining the smallest 2 groups because of sample size.<sup>4</sup>

## Findings

### Fatalities

These data demonstrate that younger patients had greater rates of unintentional and head injuries, and older patients had greater rates of assaults, torso, and extremity trauma. Of note, the case fatality rate was greatest in the youngest patient cohort (16.6%) and decreased linearly by age group. A severe injury (Injury Severity Score  $\geq 16$ ), was noted in 27.1% of all cases, and mortality was greater in this group than those with an Injury Severity Score < 16 (23.9% vs. 2.9%,  $P < .001$ ;  $\chi^2$  test). Although extremity injuries were the most frequent site of severe injury, the case fatality rate in this group was the least (9.1%), accounting for 1,012 deaths. With an isolated severe extremity (Abbreviated Injury Scale score

$\geq 3$ , with no other anatomic region injured), the case fatality rate was < 1%. Injuries to the head and neck lead to the greatest case fatality rate (39.2%). Multiple anatomic regions with severe injuries had a case fatality rate of 22.3%.

Although several reports analyzing the wounds in fatal firearm injuries have been published using autopsy data from combat and CPMS victims, surprisingly no studies describe the injury patterns in pediatric patients.<sup>5–7</sup> Our data highlight several key differences between these groups versus civilian pediatric firearm injuries. First, the mortality rate of pediatric firearm victims in our study was 11% vs 40% in CPMS.<sup>6</sup> Unique from CPMS, pediatric firearm injuries occur in a heterogeneous population with varied mechanisms, anatomic injury patterns, and case fatality rates. Simply put, there are major categorical differences between these unique pediatric cohorts (eg, the unintentionally injured toddler, the teenage suicide victim, and the urban assault victim are inherently different populations). A comprehensive, productive discussion of pediatric injuries requires an understanding of these unique cohorts of patients and recognition that not all preventive measures will be equally effective in all populations.

### Pediatric and adult populations

Second, the pediatric firearm-related pattern of injury is reflective of the trends observed in adult literature, but also differs and requires specific attention. A recent comparison between autopsy reports from adult victims of urban firearm injuries and those of CPMS victims demonstrated a similar distribution of injuries, with 59% of patients suffering a wound to the chest and 46% suffering a head wound.<sup>7</sup> A total of 1% of patients in the cohort of urban firearm injuries and 3% of patients in the CPMS group were believed to have died from an extremity wound.<sup>7</sup> It should be noted that suicides accounted for only 7% of their group.<sup>7</sup> Our results confirm this finding with approximately half of pediatric fatalities under 14 y dying from a severe head injury. Although extremity injuries are the most frequent overall location of firearm-related injury, these injuries are rarely lethal. This finding is unique from the combat literature where extremity injuries are a major source of preventable death.<sup>11</sup> Other groups have focused on the benefit of tourniquet use in the civilian setting in adult patients, finding

**Table**

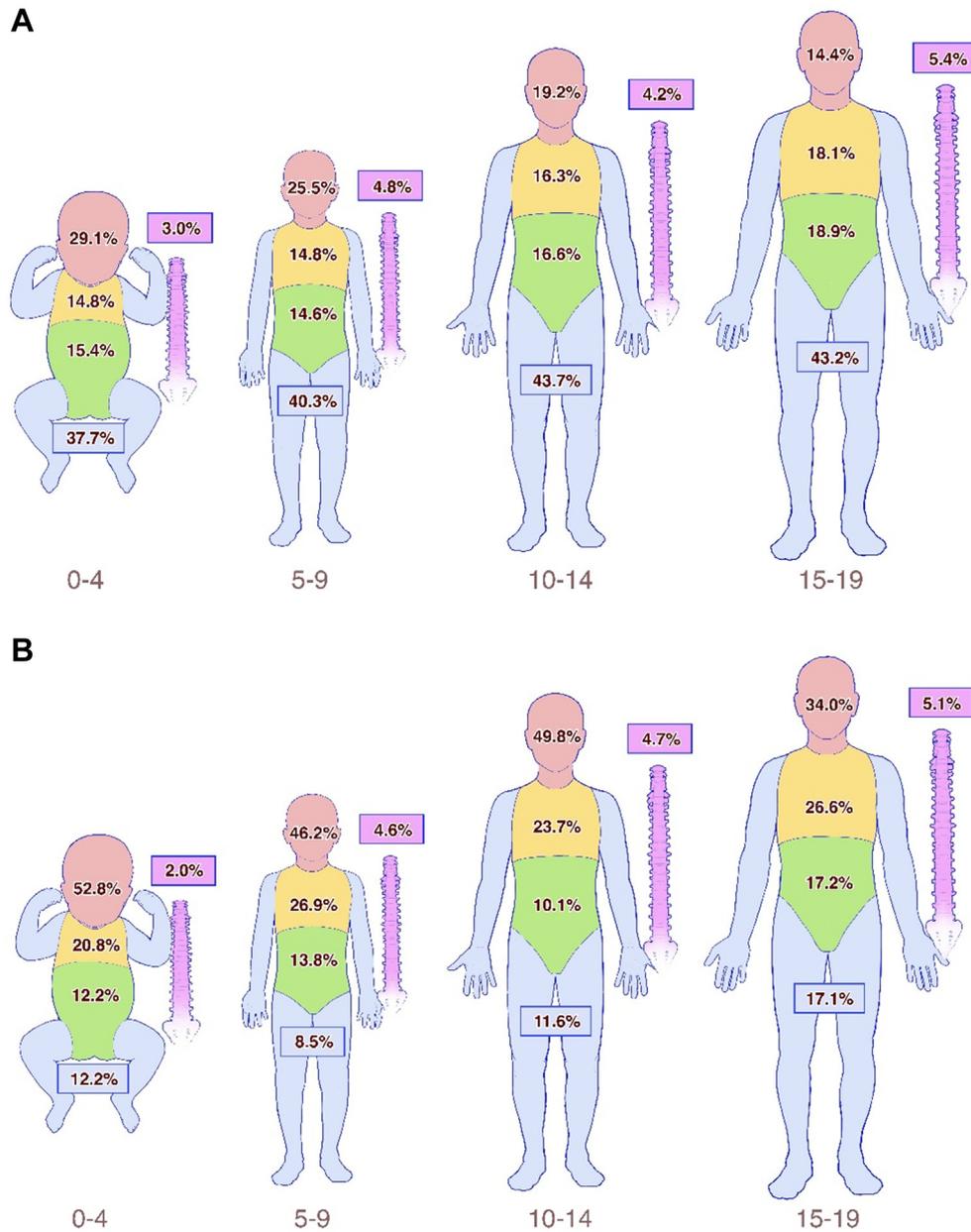
Characteristics associated with firearm injury from 2010 to 2016 in the pediatric population by categorical age ( $n = 36,581$ ).

	0 – 4 y 911 (2.5)	5 – 9 y 774 (2.1)	10 – 14 y 2,994 (8.2)	15 – 19 y 31,902 (87.2)	Mortality
Patient and injury characteristics					
Sex					
Male	612 (67.2)	493 (63.7)	2,363 (79.0)	28,628 (89.8)	11.1%
Female	299 (32.8)	281 (36.3)	629 (21.0)	3,264 (10.2)	10.2%
Race					
African American	507 (55.7)	404 (52.2)	1,619 (54.1)	20,472 (64.2)	9.6%
Caucasian	250 (27.4)	225 (29.1)	869 (29.0)	5,625 (17.6)	14.9%
Other	154 (16.9)	145 (18.7)	506 (16.9)	5,805 (18.2)	11.6%
Type of firearm injury					
Assault	454 (49.8)	411 (53.1)	1,808 (60.4)	26,363 (82.6)	9.7%
Accidental	352 (38.6)	294 (38.0)	776 (25.9)	2,746 (8.6)	7.4%
Undetermined	66 (7.2)	58 (7.5)	165 (5.5)	970 (3.0)	14.1%
Suicide	37 (4.1)	11 (1.4)	235 (7.9)	1,518 (4.8)	37.8%
Legal intervention*	< 10 cases	< 10 cases	10 (0.3)	305 (1.0)	15.1%
Shock index, pediatric age-adjusted (SIPA) <sup>†</sup>					
Presence of shock	—	316 (40.8)	983 (32.8)	10,786 (33.8)	23.6%
Mortality	16.6%	13.1%	11.6%	10.7%	11.0% (total CFR)

$n$  (%) for categorical variables.

\* Firearm injuries incurred from a law enforcement officer in the line of duty.

<sup>†</sup> Positive shock index (SI), pediatric age-adjusted for pediatric patients ages 4–6 y (SI > 1.22), ages 7–12 y (SI > 1), and ages > 13 y (SI > 0.9).



**Fig 3.** Frequency of firearm (A) injury location, and (B) severe injury (AIS ≥ 3) in pediatric patients who died, by age group. Body locations include head, chest, abdomen, extremities, and spine.

that use of a tourniquet is likely to benefit only a small proportion of patients (1.8%–4.6%).<sup>12,13</sup> Although not a specific focus of this study, our data would suggest similar futility in the pediatric firearm victim.

*Self-inflicted injury*

Third, pediatric self-inflicted injuries continue to account for a large proportion of fatalities in the group.<sup>2,9</sup> This type of injury is by far the most lethal means of suicide attempts and recently has been increasing in lethality.<sup>9</sup> As noted earlier in this report, the population suffering from self-inflicted wounds is different from the populations suffering from assaults and other forms of firearm-related injury and thus require different preventative strategies. In addition to differences in race and demographics,<sup>9</sup>

these populations display differences in geographic characteristics (urban versus rural).<sup>14,15</sup> Some of these differences in the pediatric population may be related to undertreatment of mental health problems. The problem of teenage depression and suicide is underreported but is being recognized increasingly,<sup>16</sup> as demonstrated by its discussion in the *New York Times* earlier this year.<sup>17</sup> In this article, the author notes that the rate of suicide in Americans 10–24 years of age has increased by more than 50% since 2007; however, teenagers with depression are far less likely to receive treatment for their depression than adults. Improvement in mental health in isolation, however, is unlikely to solve this problem without changes in the access children have to firearms. Any preventive measures to quell this public health epidemic will certainly fall short if this self-injurious cohort is ignored.

### Unintentional injuries

Finally, an additional point that requires mention is that, although younger patients present less frequently with firearm injuries, those who do have a greater rate of unintentional injuries and the greatest case fatality rate. The finding that younger patients are more likely to be involved with unintentional firearm injuries was also reported recently in the analysis of Los Angeles County (CA) data by Barry et al.<sup>18</sup> Pediatric and adult health care providers should be aware of the increased mortality of this younger cohort and should triage accordingly. Although more study is required to best determine how to decrease mortality in this cohort, young patients ( $\leq 14$  years) with a firearm injury should likely prompt the greatest level of trauma system activation and mandate the involvement of social service evaluation of the home situation.

### Proposals

Our analysis has important limitations. The National Trauma Data Bank is not fully inclusive of all pediatric traumatic injuries nationwide. Nonetheless, this is the first report, to the best of our knowledge, focusing on the anatomic pattern of pediatric firearm injuries, using a validated national database. These data are important not only from the standpoint of public health and injury prevention but also from the standpoint of providers who acutely manage pediatric injuries.

In conclusion, the pediatric population of firearm-related injuries are a heterogeneous population that requires a more broad, thoughtful approach to mitigate the impact of this epidemic. Research into this increasingly common public health problem, especially in the urban environment, but also outside of the inner city, is an important first step in developing strategies to address this public health crisis. Until this public health crisis is addressed in a manner that prevents shots from ever being fired, children will continue to suffer firearm-related injuries. Thus, knowledge of how these children are injured and the related patterns of injury remain vitally important to the trauma surgeon, not only for treatment but also prevention of these injuries.

### Funding/Support

The authors have no funding sources to disclose.

### Conflict of interest/Disclosure

This manuscript has not been published and is not under consideration in the same or substantially similar form in any other journal. The authors are qualified for authorship and have no conflicts of interest.

### Acknowledgments

Thank you to Eo Trueblood for his expertise illustrating [Figure 3](#).

Robert A. Swendiman, MD, MPP, MSCE\*,  
Justin S. Hatchimonji, MD, MBE  
Department of Surgery, University of Pennsylvania,  
Philadelphia, PA

Myron Allukian III, MD, Thane A. Blinman, MD,  
Michael L. Nance, MD, Gary W. Nace, MD  
Division of General, Thoracic, and Fetal Surgery, Children's Hospital of  
Philadelphia, Philadelphia, PA

\* Reprint requests.  
E-mail address: [swendr@penmedicine.upenn.edu](mailto:swendr@penmedicine.upenn.edu) (R.A. Swendiman).

Accepted 20 February 2020

### References

1. Gun violence archive 2015. <https://www.gunviolencearchive.org/>. Accessed January 28, 2020.
2. Fowler KA, Dahlberg LL, Haileyesus T, Gutierrez C, Bacon S. Childhood firearm injuries in the United States. *Pediatrics*. 2017;140:e20163486.
3. Petty JK, Henry MCW, Nance ML, Ford HR. Firearm injuries and children: Position statement of the American Pediatric Surgical Association. *J Pediatr Surg*. 2019;54:1269–1276.
4. Centers for Disease Control and Prevention. Web-based injury statistics query and reporting system (WISQARS) injury center. <https://www.cdc.gov/injury/wisqars/index.html>. Accessed January 28, 2020.
5. Smith ER, Shapiro G, Sarani B. The profile of wounding in civilian public mass shooting fatalities. *J Trauma Acute Care Surg*. 2016;81:86–91.
6. Smith ER, Sarani B, Shapiro G, et al. Incidence and cause of potentially preventable death after civilian public mass shooting in the US. *J Am Coll Surg*. 2019;229:244–251.
7. Maghami S, Hendrix C, Matecki M, et al. Comparison of the causes of death and wounding patterns in urban firearm-related violence and civilian public mass shooting events. *J Trauma Acute Care Surg*. 2020;88:310–313.
8. Sarani B, Hendrix C, Matecki M, et al. Wounding patterns based on firearm type in civilian public mass shootings in the United States. *J Am Coll Surg*. 2019;228:228–234.
9. Hatchimonji JS, Swendiman RA, Goldshore MA, et al. Pediatric firearm mortality in the United States, 2010–2016: A national trauma data bank analysis. *J Trauma Acute Care Surg*. 2020;88:402–407.
10. Cutler GJ, Zagel AL, Spaulding AB, Linabery AM, Kharbanda AB. Emergency department visits for pediatric firearm injuries by trauma center type. *Pediatr Emerg Care*; 2019. In press <https://doi.org/10.1097/PEC.0000000000001846>.
11. Champion HR, Bellamy RF, Roberts CP, Leppaniemi A. A profile of combat injury. *J Trauma*. 2003;54(5 Suppl):S13–S19.
12. Hsu Y-T, Chang DC, Perez NP, et al. Civilian firearm-related injuries: How often is a tourniquet beneficial? *Ann Surg*. 2020;271:e12–e13.
13. Carmichael H, Steward L, Peltz ED, Wright FL, Velopulos CG. Preventable death and interpersonal violence in the United States: Who can be saved? *J Trauma Acute Care Surg*. 2019;87:200–204.
14. Nance ML, Carr BG, Kallan MJ, Branas CC, Wiebe DJ. Variation in pediatric and adolescent firearm mortality rates in rural and urban US counties. *Pediatrics*. 2010;125:1112–1118.
15. Nance ML, Denysenko L, Durbin DR, Branas CC, Stafford PW, Schwab CW. The rural-urban continuum: Variability in statewide serious firearm injuries in children and adolescents. *Arch Pediatr Adolesc Med*. 2002;156:781–785.
16. McLoughlin RJ, Hazeltine M, Dacier BM, Hirsh MP, Cleary MA, Aidlen JT. Young lives cut short: The relationship between firearms and pediatric suicide. *J Trauma Acute Care Surg*. 2019;87:161–167.
17. Friedman RA. Why are young americans killing themselves? Opinion. *New York Times*; January 6 2020. <https://www.nytimes.com/2020/01/06/opinion/suicide-young-people.html>. Accessed February 16, 2020.
18. Barry WE, Barin E, McLaughlin CM, et al. Pediatric firearm injuries in Los Angeles County: Younger children are more likely to be the victims of unintentional firearm injury. *J Pediatr Surg*. 2019;54:350–353.