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Variability in firearm injury among major pediatric trauma centers across the USA

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ABSTRACT

Objectives In 2020, firearm injuries surpassed automobile collisions as the leading cause of death in US children. Annual automobile fatalities have decreased during 40 years through a multipronged approach. To develop similarly targeted public health interventions to reduce firearm fatalities, there is a critical need to first characterize firearm injuries and their outcomes at a granular level. We sought to compare firearm injuries, outcomes, and types of shooters at trauma centers in four pediatric health systems across the USA.

Methods We retrospectively extracted data from each institution's trauma registry, paper and electronic health records. Study included all patients less than 19 years of age with a firearm injury between 2003 and 2018. Variables collected included demographics, intent, resources used, and emergency department and hospital disposition. Descriptive statistics were reported using medians and IQRs for continuous data and counts with percentages for categorical data. χ^2 test or Fisher's exact test was conducted for categorical comparisons.

Results Our cohort (n=1008, median age 14 years) was predominantly black and male. During the study period, there was an overall increase in firearm injuries, driven primarily by increases in the South (S) site (β=0.11 (SE 0.02), p=<0.001) in the setting of stable rates in the West and decreasing rates in the Northeast and Mid-Atlantic sites (β=−0.15 (SE 0.04), p=0.002; β=−0.19 (SE0.04), p=0.001). Child age, race, insurance type, resource use, injury type, and shooter type all varied by regional site.

Conclusion The incidence of firearm-related injuries seen at four sites during 15 years varied by site and region. The overall increase in firearm injuries was predominantly driven by the S site, where injuries were more often unintentional. This highlights the need for region-specific data to allow for the development of targeted interventions to impact the burden of injury.

Level of Evidence: II, retrospective study

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Firearm injuries are the number one cause of death in children ages 1 year to 18 years old.

WHAT THIS STUDY ADDS

⇒ Our analysis comparing firearm injuries at four regionally distinct pediatric trauma systems noted an increase in unintentional firearm injuries, with children frequently pulling the trigger.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ This study will impact firearm violence prevention policies by underlining the importance of regionally tailored public health campaigns based on the commonly encountered mechanisms of injury in that community.

INTRODUCTION

Firearm deaths in children and adolescents are steadily increasing, with a total of 37 950 reported between 2004 and 2020. In 2016, firearm injury surpassed neoplasm as the second most common cause of death, and in 2019, it surpassed motor vehicle collisions to become the number one cause of death in children and adolescents.[1–4] The steady escalation in firearm injuries has recently further escalated,[5] despite a well-documented decrease in pediatric hospital-related visits associated with the COVID-19 pandemic.[6]

Although much has been learned about the epidemiology of pediatric firearm injury, there are still significant gaps in our understanding of this preventable epidemic. For example, of all pediatric injuries, firearm injuries are associated with one of the highest case fatality rates, particularly in young children.[7] Also distinct from other pediatric injuries, firearm injuries are often intentionally inflicted.[8] However, single-center experiences and large retrospective database analyses suggest that there may be temporal and regional variabilities in firearm injury characteristics.[7–11] Although database studies can help portray the national landscape of firearm injuries and add to the comprehension of the devastating impact gun violence has on public health, individual institutional experiences provide granular, patient-level data such as hospital resource use, massive transfusion protocol (MTP) use, imaging and procedure patterns, and injury narratives. In this study, we combine regionally diverse institutions to delve into the particulars of this granular, patient-level data across four regions of the USA.

The primary goal of this study was to describe and compare rates of pediatric firearm injuries, hospital resource use and dispositions, and patient sociodemographics across four regionally distinct study sites. The secondary objectives were to compare variations in shooters and intent to elucidate patterns in the age of patients. Characterizing these differences may facilitate the identification of modifiable factors to inform the development and implementation of more effective, region-specific, tailored injury prevention campaigns.

METHODS

Study design

We abstracted retrospective data from four level 1 and one level 2 trauma centers to include all patients under 19 who presented to the study sites from 2003 to 2018. Youths 18 and under were included if they arrived in the emergency department (ED) or were inpatients with a firearm injury during the study time frame. A firearm injury was defined as a gunshot wound or penetrating injury from a weapon that used a powder charge to fire a projectile. This includes firearm injuries from a handgun, rifle, or shotgun. Exclusion criteria included patients beyond the 19th birthday and patients with injuries from air-powered BB, pellet-type guns, and paint guns.[9] The hospital sites included one hospital system from each of the following regions of the USA: West (W), Mid-Atlantic (MA), Northeast (NE), and South or Southern (S). Each hospital system had one participating level 1 trauma center, except for the S site, which is composed of two free-standing children's hospitals (both part of a single regional healthcare system), one of which is a level 1 trauma center and one of which is a level 2 trauma center. The data from these two trauma centers are reported as combined as the hospitals are part of the same healthcare system and common electronic health record (EHR) system. The annual ED volume at each site is as follows: W=46 000, MA=102 000, NE=58 000, and S=120 000. The S site served as the lead study site. All institutions housed an individual patient's unique identifier and medical record number in their secure Research Electronic Data Capture (REDCap) database.[10] Each site was responsible for maintaining the data integrity of information at their site and submitted deidentified data to a central REDCap database housed at the lead site.[10]

Data collection

We primarily identified subjects' medical records through the respective pediatric trauma registries. The S site did not have access to trauma registry data from 2003 to 2008; in this case, International Classification of Diseases, 9th Revision (ICD-9)/International Classification of Diseases, 10th Revision, hospital discharge codes were used for subject identification (online supplemental file 1). Data were collected from the trauma registry as available, from the EHR and paper records (S site, 2003 to 2007) using ICD-9 codes. The study team created a priori a list of clinical variables with a standardized data collection form, and study personnel at each site extracted data from charts and entered these into the central REDCap database. The common data points included standardized data elements collected by the American College of Surgeons (ACS) with the National Trauma Databank and Trauma Quality Improvement Program.[11] Missing data were documented as unknown. To ensure data accuracy, the principal site investigator selected a random sample of patients and conducted an independent secondary chart review for verification, accuracy, and completeness.

Measures or variables

Demographic and patient-specific information included admission date, date of birth, gender, race, insurance type, affected body region, and Injury Severity Score (ISS).[12] Resource use variables included hospital length of stay, ED disposition, final hospital disposition, MTP use in the ED, inpatient blood transfusion, sequential lab draws and imaging, and rehospitalization. We defined MTP as the documentation of use of the hospital's MTP protocol on a patient. Recognizing that use of MTP has evolved and has been modified during the 15 years of the study period, we found it is likely that what was considered use of MTP varied from 2003 to 2018. We defined rehospitalization as a return within 1 year of discharge from the index visit for an encounter related to the initial firearm injury. Rehospitalization visits met the criteria after review by the data abstractor based on the relationship to the index visit. Visits that were unrelated to the index visit were not included. We analyzed the shooter's reported relationship to the victim (unknown, known or self) and injury intent when it was available in the records. Unknown shooters are defined as not known or unfamiliar to the victim. Known shooters are defined as recognized or familiar to the victim. We defined the firearm injury intent based on standard predetermined Centers for Disease Control and Prevention definitions: unintentional injury (fatal or non-fatal firearm injuries without evidence of intentional harm), intentionally self-inflicted (firearm suicide or nonfatal self-harm injury from a firearm), and interpersonal violence (firearm homicide or nonfatal assault injury from a firearm).[8,13]

Data analysis

Descriptive statistics were reported using medians and IQRs for continuous data and counts with percentages for categorical data. Comparisons across site and intent groups were conducted using analysis of variance for continuous variables. Kruskal-Wallis tests were used for groups with unequal variances. If distributions of residuals were non-normal and variance was also unequal across comparison groups, a mixed model adjusting for heterogenous variance was used. χ^2 test or Fisher's exact test (if expected cell counts are <5) was conducted for categorical comparisons. Linear regressions were run to test for trends in firearm injuries per 10 000 ED visits during the 15 years. Annual rates of firearm injuries (per 10 000 ED visits) were calculated as follows: for each site, total annual counts of firearm injuries were divided by the total ED volume and then multiplied by 10 000. Statistical significance was assessed at the 0.05 level. All statistical analyses were conducted using SAS V.9.4.

RESULTS

Demographics (n=1008) by site and intent

The median age of patients with pediatric firearm injury was 14 years (range 1 day old to 18 years old). Our cohort was predominately black (68%), male (77%), and insured by Medicaid (67%) aggregated across all sites. The demographics and clinical characteristics by site and injury intent are summarized in tables 1 and 2. When the documented intent was interpersonal violence, the patient's average age

Table 1 Demographics and clinical characteristics by site

Characteristics Median (25th–75th) or n (%)	Overall N=1008	S N=292	W N=253	NE N=182	MA N=281	P value
Age (years)	14 (10–16)	11 (6–14)	13 (8–14)	17 (16–18)	16 (14–17)	**<0.001**
Age groups						
0–4	126 (13)	65 (22)	38 (15)	4 (2)	19 (7)	**<0.001**
5–9	116 (11)	64 (22)	32 (13)	2 (1)	18 (6)	
10–13	208 (21)	82 (28)	81 (32)	6 (3)	39 (14)	
14–18	558 (55)	81 (28)	102 (40)	170 (94)	205 (73)	
Medicaid	672 (67)	216 (74)	156 (62)	110 (60)	190 (68)	**0.004**
Male	778 (77)	207 (71)	185 (73)	155 (85)	231 (82)	**<0.001**
Race/ethnicity						**<0.001**
Black	684 (68)	211 (73)	155 (62)	68 (37)	250 (89)	
White	120 (12)	47 (16)	12 (5)	45 (25)	16 (6)	
Asian	13 (1)	1 (0)	2 (1)	9 (5)	1 (0)	
Hispanic	118 (12)	22 (8)	41 (16)	44 (24)	11 (4)	
Multiracial	24 (3)	8 (3)	1 (0)	14 (8)	1 (0)	
Unknown	42 (4)	0 (0)	38 (15)	2 (1)	2 (1)	
Injury Severity Score						0.254
0–12	701 (73)	172 (69)	194 (77)	127 (70)	208 (75%)	
13–25	169 (18)	57 (23)	36 (14)	32 (18	44 (16)	
26–50	83 (9)	21 (8)	21 (8)	18 (10)	23 (8)	
51–75	11 (1)	1 (0)	2 (1)	4 (2)	4 (1)	

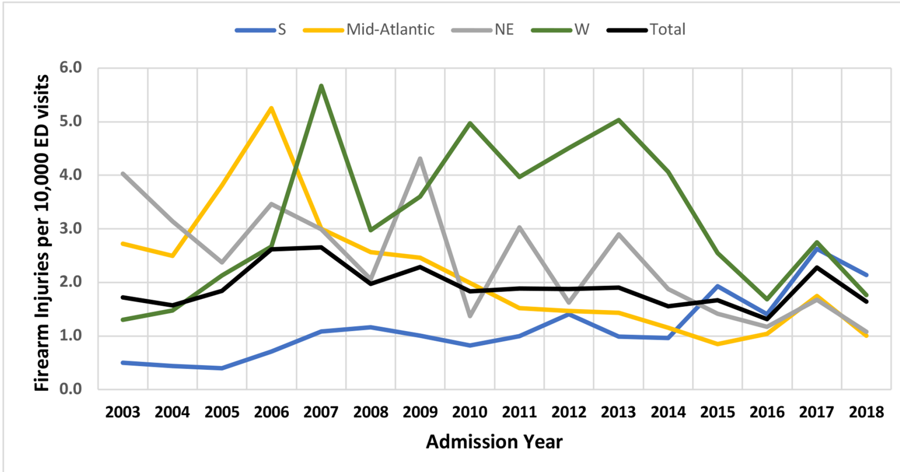
Bold indicates statistical significance.
MA, Mid-Atlantic; NE, Northeast; S, South or Southern; W, West.

was 15 (12.3 to 16.9) years. The average age for unintentional injuries was 11 (5.7 to 14.2) years. Seventy-one percent of the unintentionally injured patients had Medicaid as a payor. Patients with intentionally self-inflicted wounds were just as likely to have Medicaid (52%) as private insurance (48%). Black race was the most common for injury, which reflects the race of our cohort regardless of intent, except for intentionally self-inflicted, which was 54% non-black (table 2).

Table 2 Demographics and clinical characteristics by intent (N=1008)

Characteristics Median (25th–75th) or N (%)	Overall	Interpersonal violence N=632	Unintentional N=237	Intentionally self-inflicted N=26	Undetermined N=113	P value
Age (years)	14 (10.0–16.4)	15 (12–17)	11 (6–14)	15 (14–16)	14 (8–16)	**<0.001**
Age groups						**<0.001**
0–4	126 (13)	54 (9)	54 (22)	0 (0)	18 (16)	
5–9	116 (12)	54 (9)	44 (19)	1 (4)	17 (15)	
10–13	208 (21)	112 (17)	68 (29)	6 (23)	22 (19)	
14–18	558 (55)	412 (65)	71 (30)	19 (73)	56 (50)	
Medicaid	672 (67)	418 (66)	166 (71)	16 (52)	72 (65)	0.149
Male	778 (77)	493 (78)	169 (71)	25 (96)	91 (81)	**0.012**
Race/ethnicity						**<0.001**
Black	684 (68)	445 (71)	148 (63)	12 (46)	79 (71)	
White	120 (12)	56 (9)	40 (17)	12 (46)	12 (11)	
Asian	13 (1)	11 (2)	2 (1)	0 (0)	0 (0)	
Hispanic	118 (12)	76 (12)	26 (11)	1 (4)	15 (13)	
Multiracial	24 (2)	15 (2)	5 (2)	1 (4)	3 (3)	
Unknown	42 (5)	25 (4)	14 (6)	0 (0)	3 (3)	
ISS*						**0.004**
0–12	701 (73)	447 (72)	172 (77)	9 (38)	73 (73)	
13–25	169 (17)	102 (17)	36 (16)	10 (42)	21 (21)	
26–50	83 (9)	60 (10)	12 (5)	5 (21)	6 (6)	
51–75	11 (1)	9 (1)	2 (1)	0 (0)	0 (0)	

Anatomic scoring system that provides an overall score for patients with multiple injuries.
*Missing: ISS, n=44.
†Bold indicates statistical significance.
ISS, Injury Severity Score.



	Beta (Standard Error)	P-value
S	0.11 (0.02)	**p<0.001**
W	0.03 (0.08)	0.734
NE	-0.15 (0.04)	**0.002**
MA	-0.19 (0.04)	**P<0.001**
Total	-2.27E-6 (2.01E-6)	0.278

Figure 1 Fifteen-year trends in firearm injuries overall and hospital region from 2003 to 2018 normalized using ED visits. ED, emergency department; NE, Northeast; MA, Mid-Atlantic; S, South or Southern; W, West.

Firearm injury trends and body region of injury

Firearm injuries increased overall across the study period. This was driven by an increasing number of firearm injuries per 10 000 ED visits at the S site (β=+0.11 (SE 0.02), p≤0.001), whereas the W site had no change over time and the MA and NE sites both had a decreasing trend over time (β=−0.19 (SE 0.04), p=0.001; β=−0.0.15 (SE 0.04), p=0.002, respectively). There was no apparent increasing or decreasing linear trend at the Western site (figure 1).

Shooter and intent of injury

In almost half (44%) of the patients, chart review could not determine the shooter's status. Excluding encounters where shooter status was not documented, we found that the most common shooter type was an unknown adult at 32%. The second most commonly reported shooter was self (10%), and the third most common was another child (6%) (table 3). Unintentional shooters were involved in 38% of the visits at the S site, where self or another child was commonly involved compared with the other three sites at 1% in W, 9% in NE, and 11% in MA (p<0.001). The most common intent was interpersonal violence or intentional assault (63%, p<0.001) followed by unintentional and intentionally self-inflicted, which accounted for approximately a quarter of the intent mechanisms (27%, p<0.001); table 2).

Resource use and body region of injury

Eleven percent of patients required massive blood transfusion protocol, with 23% of patients at the S site receiving MTP. Twenty-five percent of all patients were transfused blood products, and 37% of patients who underwent imaging required repeat imaging during 2 or more days. The average 1-year rehospitalization rate was 13% of those who were discharged from their initial encounter (table 4). Two out of the four hospitals discharged fewer than 1% of their patients with firearm injury from the ED, whereas sites in S and W discharged 13% and 28%, respectively (p<0.001). Most (83%) patients from all sites were admitted to the hospital. Of those admitted, 16% were admitted to the intensive care unit (ICU), and 26% went directly to the operating room (p<0.001). The total mortality rate (ED/inpatient mortality) was 9% (table 4).

To determine the most frequently injured body part, we detailed the region of the body injured. The body regions most commonly injured were the upper leg (21%), chest (18%), abdomen, and lower leg (17%) (figure 2). The least commonly injured areas were the neck (5%) and eye (2%).

DISCUSSION

In this 15-year review of pediatric firearm injuries at four regionally distinct US trauma centers, we found notable differences in injury frequency, severity, and type across the country. This has

Table 3 Injury intent and shooter info by site

Characteristics Median (25th–75th) or N (%)	Overall N=1008	S N=292	W N=253	NE N=182	MA N=281	P value
Shooter						**<0.001**
Self	99 (10)	62 (22)	3 (1)	11 (7)	23 (8)	
Other child	60 (6)	46 (16)	1 (0)	4 (2)	9 (3)	
Other known adult	43 (4)	18 (6)	9 (4)	3 (2)	13 (5)	
Parent	21 (2)	18 (6)	0 (0)	1 (0)	2 (1)	
Family member	18 (2)	12 (4)	0 (0)	1 (0)	5 (2)	
Unknown adult/stranger	321 (3)	68 (23)	152 (60)	1 (0)	100 (35)	
Unknown*	446 (44)	68 (23)	88 (35)	161 (89)	129 (46)	
Intent						**<0.001**
Interpersonal violence	632 (63)	116 (40)	149 (59)	146 (80)	221 (79)	
Unintentional	237 (24)	110 (38)	61 (24)	12 (7)	54 (19)	
Intentionally self-inflicted	26 (3)	16 (5)	0 (0)	6 (3)	4 (1)	
Undetermined	113 (11)	50 (17)	43 (17)	18 (10)	2 (1)	

Bold indicates statistical significance.
*Unknown (shooter) means unable to be determined, not documented in the medical record.
MA, Mid-Atlantic; NE, Northeast; S, South or Southern; W, West.

multiple important implications for the development and implementation of targeted public health interventions.

Regional firearm injury hospital trends

First, our study demonstrated differing trajectories of firearm injury frequency across the country. The increase in firearm injuries in the S site despite concurrent decreases in the NE and W sites is consistent with current trends in pediatric firearm injury.[2 3] Notably, three of our sites, including the two with decreasing firearm injury frequency, were located within states that previously reported the highest rates of firearm homicide among children.[14] In reviewing the Nationwide Emergency Department Sample, a database that produces national estimates about ED visits across the country, firearm-related visits varied by geographical region. The NE region had the lowest rate, whereas the S region had the highest rate.[15] Similarly, in our study, absolute numbers of firearm injuries increased in the S site but decreased or did not change at the other sites studied. Other studies have also identified a regional trend of increased firearm injuries associated with the S site and the Midwest.[3]

Blood transfusion and MTP

Overall, one in four patients with firearm injuries within this cohort received blood transfusions. Prior studies have

Table 4 Resource use and hospital disposition

Characteristics Median (25th–75th) or N (%)	Overall N=1008	S N=292	W N=253	NE N=182	MA N=281	P value
Received massive blood transfusion in the ED	109 (11)	67 (23)	9 (4)	3 (2)	30 (11)	**<0.001**
Received blood transfusion during stay	238 (25)	100 (35)	26 (13)	27 (15)	85 (30)	**<0.001**
Hospital length of stay (days)	2 (1–6)	3 (1–7)	1 (1–5)	2 (1–6)	2 (1–6)	**<0.001**
Sequential imaging performed	369 (37)	121 (41)	30 (12)	83 (46)	135 (48)	**<0.001**
Sequential labs drawn	397 (39)	137 (47)	20 (8)	103 (57)	137 (49)	**<0.001**
ED disposition						**<0.001**
Admit to inpatient	416 (41)	105 (36)	74 (29)	82 (45)	155 (55)	
Admit to ICU	163 (16)	52 (18)	41 (16)	23 (13)	47 (17)	
Admit to OR	263 (26)	81 (28)	57 (23)	58 (32)	67 (24)	
Discharge home	109 (11)	37 (13)	70 (28)	1 (0)	1 (0)	
Transfer to another facility	8 (1)	3 (1)	3 (1)	0 (0)	1 (0)	
Death in the ED	49 (5)	13 (4)	8 (3)	18 (10)	10 (4)	
Final disposition						**<0.001**
Home	805 (80)	220 (76)	213 (84)	142 (78)	230 (82)	
Transferred to another facility	36 (3)	24 (8)	7 (3)	2 (1)	3 (1)	
Legal authority	18 (2)	4 (1)	0 (0)	2 (1)	12 (4)	
Rehab hospital	58 (6)	14 (5)	15 (6)	10 (6)	19 (7)	
Unknown	3 (0)	0 (0)	3 (1)	0 (0)	0 (0)	
Death (ED/inpatient)	88 (9)	30 (10)	15 (6)	26 (14)	17 (6)	
Rehospitalization (≥1)	133 (13)	59 (20)	13 (5)	11 (6)	50 (18)	**<0.001**

Missing: LOS, n=17; blood transfusion, n=33; sequential imaging ≥2 days of imaging; sequential labs ≥2 days of blood draws.
Bold indicates statistical significance.
ED, emergency department; ICU, intensive care unit; LOS, length of stay; MA, Mid-Atlantic; NE, Northeast; OR, operating room; S, South or Southern; W, West.

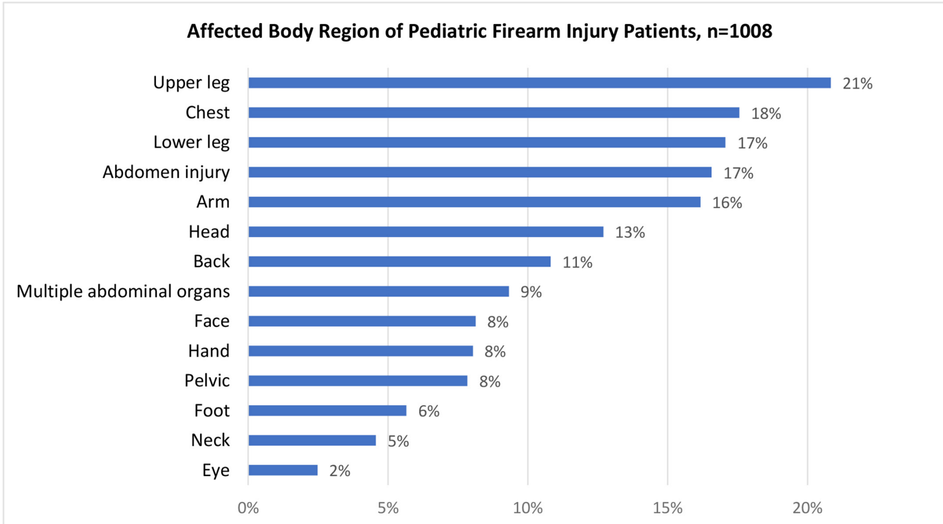


Figure 2 Body regions most affected by firearm injury. Abdomen injury includes injury only in the abdomen. Multiple abdominal organs indicates that more than one abdominal organ are involved. Face indicates only the face, not involving the head.

demonstrated up to a third of children require blood transfusions after firearm injury compared with approximately 10% of adults.[16–18] Massive transfusion that includes receipt of all three blood products occurs in only 2% to 5% of adult firearm injuries[19] compared with 11% of our pediatric cohort and 7% reported in prior studies of pediatric firearm injury patients.[20] These differences in MTP use might reflect practice variation, changes in MTP use over time, heroic life-saving measures given to pediatric victims, or hospital capabilities. It is striking that our rate of MTP was similar to the 10% given to US military patients injured in combat. Since 1963, four times as many US children have been killed by gun violence than US military personnel in combat.[21] This disturbing statistic helps explain in part why US children were as likely to receive MTP as military soldiers.

MTP use at the S site (23%) was more than double that of the next highest MA site (11%). Although it is impossible to determine the reason behind MTP use, potential contributing factors could include the younger age of the patients, the severity of the injury at the S site, hospital practice variation, or the time frame when institutions implemented MTP protocols. We highlight the use of MTP as evidence of resource use that was incurred. Of note, ISS, which is an imprecise measurement, did not seem to correlate with the frequency of MTP use.[22 23] The S site experienced a 1 day longer average length of stay and a higher percentage of patients admitted to the operating room and ICU, suggesting higher severity of injury. Notably, resource use for pediatric firearm injuries is higher than motor vehicle injuries, the next most common cause of pediatric mortality.[24] Overall, this highlights the inordinate degree of pediatric morbidity related to non-fatal firearm injuries and the important regional impact on children, families, and communities.

Firearm injury mitigation

The striking regional differences in pediatric firearm injuries demonstrated that local policies and social factors have a strong influence on child health and safety. There are policies and practices related to safe firearm storage and addressing underlying risk factors for youth violence that are demonstrated to be effective in reducing firearm injuries. Children are less likely to be killed by unintentional shootings or suicide when firearms are locked separately from ammunition.[25 26] Some states have policies that hold adults accountable for this practice.[27] These policies and strategies have been shown to reduce harm, for example, state-legislative policies that require safe storage along with violence intervention programs, and community and hospital based potentially can reduce firearm injury.[16–18 25 28] Safe storage of firearms in the homes children visit have been shown to be an effective strategy to reduce harm. Differences in pediatric firearm injuries may (at least in part) be explained by regional differences in gun access legislation. States with weak gun laws have more child-involved shootings and higher pediatric firearm mortality than states with stronger gun laws.[29] Child access protection (CAP) legislation can be particularly impactful in mitigating pediatric firearm injuries. There are two distinct types of CAP laws: recklessness and negligence. Negligence CAP laws, which are associated with a reduction in youth firearm fatalities, hold the gun owner liable when a child injures another with a firearm if the gun owner did not have the firearm safely locked and stored unloaded. Recklessness CAP laws, in contrast, hold the gun owner liable only if the gun owner provides the gun to a child and that child injures another person. Recklessness CAP laws do not impact firearm mortality.[30] Both W and NE sites have negligence CAP laws, and the data show that these states have the lowest child firearm mortality rate and stable and decreasing frequency of firearm injuries when compared with the other sites. The NE site, which is in a state that had a negligent CAP law throughout the study period, showed a statistically significant decrease in firearm injuries during the study period, whereas the W site enacted a CAP law during the last 4 years of the study and also showed a downward trend of firearm injuries.[31] The S site, with an increasing frequency of firearm injuries in children, and the MA site, with the highest child firearm mortality rate in our study, were both in states with recklessness laws which are demonstrated to be ineffective in reducing firearm mortality.[31]

Hospital volence intervention programs (HVIPs) have been shown to reduce recidivism.[32] Implemented broadly, HVIPs have the potential to reduce firearm injury through the modulation of risk of firearm injury and help promote recovery through wraparound services. Both the MA site and the W site had HVIP implemented during the study period; this could have potentially reduced the number of injuries seen due to their impact.

Comparison of shooters and intent of injury

Similar to prior reports, most pediatric firearm injuries in our study were intentional.[4] However, our sites had a higher rate of unintentional firearm injuries (24%) than the national average of non-fatal firearm injuries at 21% and fatal firearm injuries at 6.6%.[33] There have been conflicting data in the literature regarding the shooter's age (adult vs. child) in child firearm injuries.[20 21] Our results demonstrate regional differences, with child shooters most common in the S region and unknown adult shooters most common in W. These regional differences may explain conflicting findings in the literature and support the need for regionally specific assessment and interventions. For example, our previous work in the S site found that over half of the parents stored their firearms insecurely,[34] and other studies have noted that nearly 50% of persons in the state of the S site owned a gun,[35] which may be related to the high rate of firearm injuries inflicted by other children in this region,[22] whereas reported gun ownership rates were lower in the states of every other site.

Limitations

This study has several limitations. As with all retrospective reviews, our data are subject to misclassification bias and are best used for descriptive purposes. To reduce data abstraction errors, we used a standard chart abstraction form across all sites. Additionally, the principal site investigator provided a secondary review of a sample of charts for accuracy at each location. Although all sites are ACS-certified level 1 or 2 trauma centers with an expectation of entering data similarly using common data points, variability in data entry cannot be excluded. Each site included the standard data points from their trauma registry or EHR. All data entered were based on data requirements that aligned with each site's trauma activation criteria that could vary by state and which could reflect on why some hospitals had a higher ED discharge rate. The number of unintentional injuries was much higher in general and in the S center more specifically. Since the S center relied on ICD-9 codes for 5 years of abstraction, given the absence of registry data, with the growing body of evidence that demonstrates that administrative coding misclassifies a significant proportion of firearm injury intent, with a risk of overclassifying unintentional injuries, this is an additional limitation to our study. However, a higher number of guns in the households in the S region may also contribute to a higher number of unintentional injuries in children; in addition, each medical record was reviewed for documentation of intent; thus, inaccuracy of unintentional injuries is less likely. Data accuracy is particularly relevant regarding the narrative surrounding the injury intent and the relationship between the victim and shooter, and we are limited regarding the extent of missing and incomplete data of this nature. In many cases, data were unavailable due to a lack of documentation or limitations of the databases; this could potentially skew the shooter data type as one site, the MA site, had 46% incomplete shooter types or unknown shooters. Although we highlight the frequency of children as the shooter and unintentional shooters, many shooters were unknown (44%). The lack of data on shooter type is likely due to the shooter being unknown to the victim or lack of EHR documentation or not being inquired about by the treating medical team. Therefore, the number of children who fired a gun or the number of known parents or adult shooters could be higher than reported. In addition, the sites represented large regional pediatric trauma facilities but may not fully represent all injuries or trends within a region. However, all were the largest pediatric referral centers in that region. Finally, the noted variability in injury patterns may reflect regional trends, population changes over time, or referral patterns. The variations in firearm injury trends at each site may not represent the geographical region and may reflect local care and patterns. In addition, although the high use of MTP is notable and has not been previously reported, it is a relatively new trauma-based modality, and its implementation most likely varied between institutions.[36 37] An additional limitation may include missed injuries since some pediatric patients could have been managed at other regional trauma facilities, particularly adolescents sent to adult trauma centers, impacting the number of patients incorporated into the study. Two of the four sites only managed pediatric patients under 16 years of age, so gun injury data are unavailable for the 16 to 18 age group, limiting injuries to the younger adolescents. In the cumulative data, this may account for the younger age of many of our patients and the differences in intent across sites. This study is descriptive of these four institutions and cannot necessarily be generalized across all trauma centers.

CONCLUSION

We identified an unacceptably high number of pediatric firearm injuries; every pediatric firearm injury is one too many. During the study time frame, firearm injuries moved from the third leading cause of death to the leading cause of death in children, first surpassing cancer and then surpassing motor vehicle injuries. Furthermore, we describe a statistically significant increase in firearm injury at the S site, a higher frequency of unintentional injury, and a higher percentage of children who fired the weapon compared with the national average. This knowledge can inform more targeted representative region-specific injury prevention initiatives. These variations in firearm injury highlight the different phenotypes of gun violence. National prevention initiatives will likely fail, given this heterogeneity, if efforts are not focused on the predominant local and regional differences. Thus, a detailed study of regional epidemiology is essential to design appropriate and targeted public health solutions. Policymakers should focus on rural, urban, suburban, statewide, and regional strategies to reverse this trend in firearm injury and death in children and adolescents.

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