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Pediatric firearm injuries: A Midwest experience☆

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ABSTRACT

Introduction: Firearm injuries remain a significant public health concern. As a Level 1 Pediatric Trauma Center with a wide and diverse catchment, we sought to define our own experience as well as identify the affected patient population.
Methods: A retrospective review was conducted utilizing our institution's trauma registry including all pediatric patients (age ≤ 17 years) who presented with a firearm injury between 2012 and 2017.
Patients were stratified by age group as well as by geographic location. Outcomes as well as circumstances of the shooting were measured.
Results: A total of 236 patients were included. One hundred thirteen patients (47.9%) were ≤12 years while 123 (52.1%) were between the ages of 13 and 17 years. The younger group had a 52.2% operative intervention rate while the older group had a 37.2% operative intervention rate ($p = 0.005$) while there was no difference in mortality rate. Patients in the younger group tended to be injured by someone who was known to the patient (self: 22.1%, family/friend: 44.3%) as an accidental shooting (61.9%) while patients in the older group were usually injured by a stranger (58.5%) as an assault (61.8%). When stratified by location, the majority of patients were from large cities. However, after adjusting for population, the firearm injury rate was the highest in the small cities. The majority of the shootings in these small cities were accidental, even after stratifying by age (young group: 81.4% small cities vs 50% large cities, $p = 0.0008$%; older group: 62.5% small cities vs 25.2% large cities, $p = 0.0005$).
Conclusions: Although gun violence in the pediatric population is traditionally viewed as an "urban" problem among teens, our research shows that young children also suffer the consequences of firearm injuries and that rural areas are afflicted particularly by accidental firearm discharges. This may represent a new targeted audience for outreach.
Level of evidence: III.

Firearm injury remains a significant public health concern despite the attention it has received nationally. Firearm-related deaths are the third leading cause of death among U.S. children aged 1–17 years [1]. The U.S. has the highest rate of firearm-related death in children compared to any other country in the world [2]. It accounts for 30,000 deaths a year and 160 nonfatal injuries a day [3,4]. Healthcare costs from firearm related injuries have been estimated at $70 billion annually [5].

The causes and possible solutions to the firearm epidemic remain incredibly nuanced and multifactorial. Kansas City represents a unique location to study this public health crisis. It is a border city, encompassing both Missouri and Kansas, and also represents one of the largest cities in the Midwest. However, despite being one of the most populated cities, it is surrounded by a number of small rural cities.

Missouri and Kansas have consistently demonstrated high volume of firearm violence, ranking 5th and 19th in firearm mortality in the nation, respectively [6]. While traditionally firearm violence has been viewed as a problem of inner-city violence, the states with the highest rates of firearm death are among the least populated (Table 1A).

Missouri and Kansas are among the states with the least restrictive firearm regulations (Table 1B). Studies have also suggested that increased laxity in gun laws has been associated with increased rates of firearm-associated suicide and homicide [5–12]. However, studies of gun laws are highly generalizable and can only suggest correlations but not causation.

Given our unique location and catchment, we sought to better understand the pediatric patients who are injured by firearms by

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Table 1A
State firearm death rate 2017 [6].

State firearm death rate rank	State	Firearm death rate per 100,000
1	Alaska[a]	24.3
2	Montana	23.2
3	Alabama	23.1
4	Louisiana	21.5
5	Missouri[a]	21.38
6	Mississippi[a]	21.2
7	Arkansas[a]	20.4
8	Wyoming[a]	19.5
9	West Virginia[a]	19.2
10	New Mexico	18.9
19	Kansas[a]	16.0

[a] States with constitutional carry.

examining their epidemiology and outcomes, as well as identifying if there were any differences in presentation or outcomes based on the patient's geographic location.

1. Methods

We conducted a retrospective review of all pediatric patients (aged <= 17 years) who presented to our institution from January 1, 2012 to December 31, 2017 (IRB#00000680). The study protocol was approved by the Children's Mercy Hospital Institutional Review Board in compliance with all applicable federal regulations governing the protection of human subjects. Children's Mercy Hospital is the only Level-1 pediatric trauma centers in the region, serving a 300-mile catchment in Western Missouri and Eastern Kansas.

The electronic medical records and trauma registry were reviewed for each patient. Data extracted included: patient demographics, timing and location of shooting, circumstances of shooting, type of firearm, length of stay (LOS), and outcome. The circumstances of shootings were as defined: if there was an intention to harm, regardless if the patient was the intended victim, versus unintentional. The definitions were based on physician, prehospital, and social worker notes.

2. Results

There were 236 patients who presented to our institution with firearm injuries from 2012 to 2017. As the etiology of firearm injuries has been demonstrated to be different based on age, we divided our patients into a younger group (ages 12 years or less) and older group (ages 13–17 years). Nearly half of our cohort was in the younger group (n = 113, 47.9%) while half were teenagers (n = 123, 52.1%) (Table 2). Both age groups had a male predominance. The younger group tended to require more operative interventions (52.2% vs 37.2%, $p = 0.005$) as well as ICU level care (23.9% vs 11.5%, $p = 0.006$).

There were no differences in injury severity score, length of stay, or mortality between age groups. However, the younger group was more likely to be injured by a minor (35.4% vs 13.8%, $p < 0.001$), specifically a family member or friend, while the older group was more likely to be injured by an unknown assailant (31.9% vs 58.5%, $p < 0.001$). Accordingly, the shootings of the younger group were more likely to be unintentional (61.9% vs 32.5%, $p < 0.001$), while the shootings of the older group were more likely to be related to assault (33.6% vs 61.8%, $p < 0.001$).

Patients were then traced based on the geographic location of their shooting, and accordingly, city population. The majority of patients from both age groups were from large cities (55.8% of the younger group and 75.6% of the older group were from cities with population > 100,000 people). However, when we examined the incidence by population of the city, we found that the highest incidence was actually in the smallest cities. These zip codes were analyzed by their median income. The highest incidence of firearm injuries occurred in the lowest bracket of median income in both age groups.

We then stratified our patients again by age and city size. In children less than 12 years old, patients from the larger cities were younger (smaller cities 7.9 years vs larger cities 5.9 years, $p = 0.007$) and were more likely to be black (Table 3). Although there were no differences

Table 1B
Gun laws by state.

Subject/law	Missouri	Kansas
State permit required to purchase?	No	No
Firearm registration?	No	No
Owner permit required?	No	No
Permit required for concealed carry?	No	No
Permit required for open carry?	No	No
Assault weapon law?	No	No
Magazine capacity restriction?	No	No
Background checks required for private sales?	No	No
Safe storage?	No	No
Child access prevention laws?	Yes	No

Table 2
Demographics of firearm injuries in children.

	Age ≤ 12 years (n = 113)	Age 13–17 years (n = 123)	P-value
Age (years ± SD)	6.7 ± 3.8	15.0 ± 1.2	<0.001*
Male (%)	76.1	83.7	0.141
Race (%)			
Black	43.3	42.3	0.866
White	40.7	30.1	0.069
Other	16.0	27.6	0.023*
Operative intervention (%)	52.2	37.2	0.005*
Blood transfusion (%)	23.9	15.0	0.047*
ICU (%)	23.9	11.5	0.006*
Relationship of shooter (%)			
Self	22.1	19.5	0.621
Family/friend (child)	35.4	13.8	<0.001*
Family/friend (adult)	8.9	2.4	0.270
Unknown	31.9	58.5	<0.001*
Circumstances of shooting (%)			
Accidental	61.9	32.5	<0.001*
Assault	33.6	61.8	<0.001*
Suicide	1.8	4.9	0.187
ICU LOS (days ± SD)	5.9 ± 8.0	5.1 ± 4.7	0.679
Total LOS (days ± SD)	4.3 ± 9.7	3.6 ± 7.7	0.549
ISS (average ± SD)	6.0 ± 6.3	5.1 ± 5.9	0.238
Mortality (%)	8.8	3.5	0.069

* $p < 0.05$.

Table 3
Demographics of firearm injuries in young children (age ≤ 12 years).

	Population < 50,000 (n = 43)	Population > 50,000 (n = 70)	P-value
Age (years ± SD)	7.9 ± 3.6	5.9 ± 3.8	0.007*
Race (%)			
Black	16.3	58.6	<0.001*
White	72.1	20.0	<0.001*
Other	11.6	21.4	0.185
Operative intervention (%)	48.8	52.9	0.678
Blood transfusion (%)	11.6	30.0	0.024*
ICU (%)	18.6	27.1	0.301
Relationship of shooter (%)			
Self	25.6	20.0	0.486
Family/friend (child)	48.8	20.0	0.001*
Circumstances of shooting (%)			
Accidental	81.4	50.0	<0.001*
Assault	14.0	44.3	<0.001*
Suicide	2.3	1.4	0.726
ICU LOS (days ± SD)	4.3 ± 4.8	6.6 ± 9.1	0.534
Total LOS (days ± SD)	3.0 ± 5.6	5.1 ± 11.4	0.258
ISS (average ± SD)	5.9 ± 6.0	5.5 ± 5.3	0.766
Mortality (%)	2.3	12.9	0.056

* $p < 0.05$.

Table 4
Demographics of firearm injuries in older children (age 13–17 years).

	Population < 50,000 ($n = 24$)	Population > 50,000 ($n = 99$)	P-value
Age (years ± SD)	14.8 ± 1.1	15.0 ± 1.2	0.295
Race (%)			
Black	12.5	49.5	0.001*
White	70.8	20.2	<0.001*
Other	16.7	30.3	0.180
Operative intervention (%)	54.2	28.3	0.016*
Blood transfusion (%)	16.7	13.1	0.652
ICU (%)	16.7	17.2	0.953
Relationship of shooter (%)			
Self	50.0	12.1	<0.001*
Family/friend (child)	16.7	13.1	0.652
Unknown	25.0	66.7	<0.001*
Circumstances of shooting (%)			
Accidental	62.5	25.2	<0.001*
Assault	25.0	70.7	<0.001*
Suicide	12.5	3.0	0.053
ICU LOS (days ± SD)	7.3 ± 4.6	4.3 ± 4.7	0.273
Total LOS (days ± SD)	4.3 ± 6.6	3.5 ± 8.3	0.632
ISS (average ± SD)	4.8 ± 5.4	5.2 ± 6.1	0.856
Mortality (%)	4.2	3.0	0.778

* $p < 0.05$.

in ISS, operative intervention or ICU admission, patients from larger cities had a higher incidence of blood transfusions (11.6% vs 30%, $p = 0.024$). This may be because this group was younger, and so there may have been some bias to transfuse at a lower threshold. Patients from smaller cities were more likely to be shot by an underage family member or friend (48.8% vs 20.0%, $p = 0.001$), and their shootings were more likely to be unintentional (81.4% vs 50%, $p < 0.001$). Shootings in larger cities were more likely to be the result of an assault (14.0% vs 44.3%, $p < 0.001$). There were no differences in length of stay or mortality.

When we separated the children from the older group into those from large cities versus those from small cities, we found no difference in age but again, older children from large cities were more likely to be black (Table 4). Patients from smaller cities were more likely to have operative interventions (54.2% vs 28.3%, $p = 0.016$). They were also more likely to have sustained a self-inflicted injury (50.0% vs 12.1%, $p < 0.001$). However, this was not attributed to suicide (12.5% vs 3%, $p = 0.053$), but was reported as unintentional in nature (62.5% vs 25.2%, $p < 0.001$). Conversely, patients from larger cities were more likely to be injured as a result of an assault (25.0% vs 70.7%, $p < 0.001$). Again, there were no differences in length of stay or mortality.

3. Discussion

While firearm injuries have been recognized as a national public health issue, the etiology of firearm injuries has been variable across the country. California has demonstrated significant intrastate variation in firearm mortality; certain regions had high rates of firearm-related homicide while other regions had high rates of firearm-related suicide [13]. This type of information remains essential for targeted interventions and resource allocation as the solutions to firearm injuries may also vary according to region.

We reported an incidence of 236 firearm injuries in 6 years, or 39.3 per year (Table 5). Upon review of the literature, our series reports one of the highest numbers of pediatric firearm injuries despite being considered a smaller city [14–20]. We identified only a single study with a higher incidence of pediatric firearm injuries, in which 2 pediatric trauma centers from St. Louis reported 398 firearm injuries over 5 years, or 79.6 per year [20].

Although both Kansas City and St. Louis are not among the largest cities in the U.S., both cities have had significant firearm-related morbidity and mortalities. As mentioned before, Kansas and Missouri have the least stringent firearm regulations in the country. Nationally, strict firearm laws (i.e. those that curb firearm trafficking, strengthen background checks, improve child safety, ban military-style assault weapons, or restrict firearms in public places) were associated with fewer firearm related homicides while weaker laws were associated with higher rates of firearm related suicides [9,10]. Even laws that do not have direct associations with firearms may impact firearm related incidents. Lee et al. found that states with Stand Your Ground laws (laws that establish that a person may defend one's self or others against threats or perceived threats, even to the point of applying lethal force) had significantly increased rates of overall firearm injuries in the pediatric population, particularly by unintentional firearm discharges [21]. Missouri repealed its permit to purchase handgun law in 2007. Overall, even after controlling for other factors including unemployment, poverty, and crime, there was a 25% increase in firearm related homicide and 16% increase in firearm related suicide after repeal of this law [8].

More recent studies suggest that Child Access Protection (CAP) laws reduce pediatric firearm injuries. Hamilton et al. reported that strong CAP laws correlated with reductions in overall, self-inflicted, and unintentional pediatric firearm injuries [12]. Madhavan et al. found that stricter gun legislation and CAP laws were associated with fewer overall pediatric firearm-related deaths and firearm suicides, although they also reported that there were no differences in firearm homicides [11].

Firearm regulation remains a hotly debated topic. Opponents argue that regulations do not aid in stopping shootings from illegally obtained firearms. Additionally, if firearm injuries are the result of crime and violence, then the lack of firearm regulations may not be consequential. But while lax regulations likely contribute to firearm injuries, they are by no means the only cause, nor would stronger regulations be the only solution.

Socioeconomic factors are also significant contributors of violent crimes and firearm injuries. Our data reflect that the highest incidence of firearms injuries came from the areas were lower median household incomes. A study from Atlanta measured communities based on variables including unemployment, education level, poverty rate, median income, business growth, and housing vacancies. "Distressed communities" (i.e. those with increased unemployment/poverty and decreased education) were found to be at significantly higher risk of pediatric

Table 5
Pediatric firearm injury reports [13–20,26].

City, state	Hospital	Ages of patients (years)	Pediatric firearm injuries per year	City population
St. Louis, MO	St. Louis Children's Hospital, Cardinal Glennon Hospital	0–16	79.6	302,838
Kansas City, MO	Children's Mercy Hospital	0–17	39.3	491,918
Miami, FL	Jackson Memorial Medical Center	0–16	37	470,914
Los Angeles, LA	Children's Hospital Los Angeles, USC + LAC, UCLA	0–17	30.4	4 million
Detroit, MI	Children's Hospital of Michigan	0–17	28.9	673,104
Houston, TX	Children's Memorial Hermann Hospital	0–15	23.9	2.3 million
Birmingham, AL	Children's Hospital of Alabama	0–19	19.4	210,710
Denver/Aurora, CO	Children's Hospital Colorado, Denver Health Medical Center	4–17	16.1	716,492

firearm violence [22]. The St. Louis study of pediatric firearm injuries also found clustering of firearm injuries among the poorest areas of the city [20].

Our region also seems to have a unique patient population affected by firearms. Other studies have found that the majority of pediatric patients injured by firearms are teenagers, lending credence to the stereotype that these patients are "inner city gang members". In St. Louis, 67.7% of patients were between 14 and 16 years old, while in the Denver study, 68% of patients were between 15 and 17 years old [15,20]. In contrast to this, nearly half of our patients are less than or equal to 12 years of age. Younger children were also more likely to be injured by unintentional firearm discharges while older children were more likely to be victims of assault, which are also consistent with the literature [16,23,24]. Our younger patients were also more likely to require operative intervention as well as ICU admission, a similar finding to other studies that ascertain that younger patients sustain more significant injuries from firearms [20]. This is likely related to unintentional discharges at very close range, and smaller body surface leading to more devastating injuries.

While 67% of all of our patients were from the Kansas City metropolitan area, disproportionately higher rates of firearm injuries came from smaller cities based on population. Thus, pediatric firearm injuries may be an understated issue in smaller cities. We speculated that smaller rural areas may have more guns per person than in larger urban areas. However, gun ownership data as well as data regarding firearm storage/safety/training in our patient population could not be obtained as part of this retrospective review.

Our data demonstrate that patients from smaller cities are more likely to be injured by unintentional discharges and by known underage shooters. Younger children from smaller cities are more likely to be shot by another child while older children from smaller cities are more likely to sustain self-inflicted gun related injuries. Conversely, children from larger cities are more likely to be shot by an unknown assailant with an intent to harm. This suggests that there may be a difference in targeted interventions aimed at decreasing firearm injuries based on location.

Prior studies have also identified differences between pediatric firearm patients based on location. While overall pediatric firearm death rates were actually equal among urban and rural areas [2,23], unintentional firearm discharges were more common in rural areas [23,24]. Firearm-related homicides were found to be higher in urban counties [23]. The highest rates of hospitalization were for assaults in urban teenagers [24]. Suicide rates by both firearms and hangings were reported to be disproportionately higher in rural areas [23,25]. We found no difference in suicide rates between communities in our study.

The limitations of this study include the fact that although we are the largest pediatric trauma center in the region, this remains a single-center experience. We have no information on pediatric patients who may have been taken to other trauma centers. Additionally, our analysis did not include towns that did not have pediatric firearm victims sent to our institution. Given the retrospective nature of this study, we were limited in what data we could extract, particularly with regards to gun ownership practices. As such, although we may speculate, a study that includes all hospitals in the region would yield stronger conclusions. Patients who were declared dead on scene were also not included in data capture and analysis. This is particularly salient for our relatively low incidence of firearm-related suicides, as it is speculated that the incidence is actually higher but not captured as these patients did not survive to transport or were taken to another facility.

Contrary to public perceptions, there are a significant number of pediatric patients injured by firearms who are outside the exposure of inner-city violence. The etiology of firearm injuries in pediatric patients is different based on age as well as patient environment. Firearm injuries in large cities may benefit from more violence intervention and crime reduction strategies. Firearm injuries in small cities may benefit from strategies focusing on gun storage, safety, and supervision. This study helps to reinforce the need for a closer scrutiny of a trauma center's population in order to appropriately direct prevention and education efforts.

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