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Firearm Injuries to the Wrist and Hand in Children and Adults: An Epidemiologic Study

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Abstract

Background: Gunshot wounds (GSWs) to the wrist and hand are a major health and economic burden in the United States. There are few studies examining the circumstances and epidemiological factors surrounding these injuries. This study assesses the epidemiological factors, as well as the shooting circumstances, injury details, and surgical management of wrist and hand GSWs in children and adults. **Methods:** Medical records and radiographs were reviewed for all patients with ballistic injury to the wrist or hand treated at an urban academic level 1 trauma center from 2016 to 2019. Fisher exact and Pearson χ^2 tests were used to assess differences between groups. **Results:** Two hundred forty-nine victims (29 children, 220 adults) with complete documentation were identified. Among 180 victims with known shooting circumstances, 132 (70%) were shot by another person and 110 (65%) were injured by intentional gunfire. Eighty-seven victims (35%) suffered a concurrent GSW to another body region. Metacarpal fracture was the most commonly diagnosed bony injury (37%), followed by proximal phalanx fracture (25%). One hundred twenty-nine victims (52%) underwent surgery following their injuries. Nerve discontinuity was diagnosed in 27 victims (11%), while 20 victims (8%) had vascular disruption. There was no significant difference between children and adult victims' type of fracture, concurrent injuries, rates of surgery, or in the most common fracture fixation method. **Conclusions:** Most wrist and hand GSW victims were injured due to intentional, non-self-inflicted gunfire. Most patients present with hand fractures, and fortunately, nerve and vascular disruptions are uncommon.

Keywords: ballistic, GSW, hand, trauma, wrist

Introduction

In the United States, an estimated 39 000 people die in firearm-associated incidents each year.[1] In 2019, gunshot wounds (GSWs) accounted for 20% of overall deaths in those aged 15 to 34 years.[1] Ballistic injuries have become a major economic burden for the American health care system, with firearm-associated hospitalizations costing nearly $20 billion per year.[2]

Firearm-associated injuries can be classified according to the velocity of the projectile. In noncombat incidents, most injuries are caused by handguns[3-5] and are classified as low-velocity GSWs, given that these weapons fire at muzzle velocities lower than 2000 feet per second.[6,7] Among nonfatal GSWs in civilians, previous studies have shown that more than 70% of unintentional GSWs and 45% of assault-related GSWs involve the extremities.[8] Gunshot wounds to the wrist or hand notably have the potential to cause substantial morbidity due to the proximity of neurovascular structures.[3,9,10]

At this time, most of the literature concerning ballistic injury to the wrist or hand pertains to wartime injury.[11-15] As such, the literature regarding epidemiological factors surrounding civilian firearm injury to the wrist and hand remains scarce. Previous studies examining firearm injuries to this region are dated,[16,17] focus on wound management,[3,18,19] or have small sample sizes.[20,21] However, previous authors have reported that early treatment of civilian wrist and hand injuries is essential in reducing morbidity risk.[22-24] There remains a need for understanding the circumstances regarding firearm injury to this region, as well as the medical impacts of these injuries.

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Previous studies have shown that Black patients in the United States suffer from disproportionately higher rates of gun violence; they are more likely to both present to emergency room for a GSW and be hospitalized following a GSW.[25,26] However, given the fact that Caucasian and Black GSW victims may differ in terms of most common mechanism of injury (self-inflicted vs violence-related),[27] it remains unclear whether there is any racial disparity with regard to rate of nerve or vascular injury following a GSW.

This study sought to expand our understanding of gunshot injuries to the wrist and hand by reporting current epidemiological factors, concurrent nonhand GSWs, the incidence of neurological or vascular injury, and methods of fixation used in a large cohort of victims who presented to a level 1 trauma center. We hypothesized that at our center, most GSWs would be non-self-inflicted, and that there would be no difference between children and adults with respect to these factors. We also hypothesized that Black victims would be less likely to present with self-inflicted GSWs, when compared with Caucasian victims.

Methods

This study was performed at an urban academic level 1 trauma center in the United States. Following institutional review board approval, radiological reports and indications for imaging between April 2016 and June 2019 were queried for the following terms: "ballistic" OR "gunshot" OR "gun shot" AND "hand" OR "wrist." This generated 542 patient reports. Upon full review, reports documenting gunshot injuries outside of the hand/wrist (n = 159), patients without gunshot injuries (n = 22), and duplicates (n = 26) were excluded. All firearm types were included in the study, including BB guns, handguns, shotguns, and rifles.

Demographic information for victims was collected through the institutional electronic medical record. Data including age, sex, and race were obtained in automated fashion, while zip code, hand dominance, and insurance information were collected manually. Victims missing accompanying clinical treatment (n = 39) were excluded, leaving 260 patients for the final analysis. After removing 11 anonymized patients who were missing age information, 29 children and 220 adults remained for age-based analysis (Figure 1). Victims were classified as children (0-18 years) or adults (>18 years). Zip codes were classified into urban and rural designations using data files published by the US Federal Office of Rural Health Policy.[25]

A manual review of emergency department provider notes, radiological reports, operative notes, and follow-up notes was performed for each victim. Variables including GSW location, presence and location of bony injury, shooting details, and concurrent GSWs were recorded.

For victims treated surgically, the time between initial presentation and surgery, number of surgeries, type of surgeries, presence of neurological or vascular injury, and method of fixation were recorded. Neurologic symptoms were recorded from emergency room and consult evaluations. Among patients treated surgically, the continuity of nerve and vascular structures were noted.

Statistical Analysis

Descriptive statistics were produced for the entire study population. Statistical comparisons between children and adults were calculated by using Fisher exact and Pearson χ^2 analysis. Statistical significance was defined as $P < .05$.

Results

Demographic data for children and adults are reported in Table 1. The median age for children was 15 years (range: 2-17 years) versus 28 years (range: 18-83 years) among adults. Ninety-one percent of victims were men. Seventy-six percent of the victims were Black. Fifty-three percent of all victims were uninsured. With the exception of age, there was no statistically significant difference regarding these demographic characteristics between children and adults.

A majority of the injuries were perpetrated by someone other than the victim in both children (n = 18, 62%) and adults (n = 114, 52%). Of the victims who shot themselves, the vast majority (n = 54, 95%) did so accidentally. Among the 170 victims for whom the shooting circumstances were documented, most injuries resulted from intentional gunfire. Black victims were more likely to have been injured by another person (n = 126, 84%, $P < .01$) and in nonaccidental violence (n = 100, 79%, $P < .01$) (Table 2). However, in between children and adult victims, there was no difference in shooting characteristics (Table 3).

Metacarpal fracture was the most common injury in the overall cohort (n = 93, 37%), followed by proximal phalanx fracture (n = 63, 25%) (Table 4). Neurologic sensory changes on physical examination were noted in 5 children (17%) and 52 adults (24%). During surgical exploration, nerves were in discontinuity in 24 adults (11%), as well as in 3 children (10%). Intraoperatively, the nerves injured most often in the overall cohort were the ulnar nerve (n = 9, 3.5%) and the digital nerves (n = 7, 2.7%). Two (7%) children and 18 (8%) adults were noted to have vascular disruption intraoperatively. Of these 20 victims, 4 had surgical repair or reconstruction of vasculature. There was no statistically significant difference in these 2 groups with regard to fracture distribution ($P > .30$), neurological injury, ($P = .82$), or vascular injury ($P = .79$). However, Black patients were significantly less likely to suffer either intraoperatively diagnosed nerve (n = 14, 7%, $P < .01$) or vascular (n = 9, 5%, $P < .01$) injury (Table 2).

Fifty-two percent of all victims underwent wrist or hand surgery for their GSWs. Most patients required a single surgery (n = 104, 81%). Nearly half of all surgeries were per-

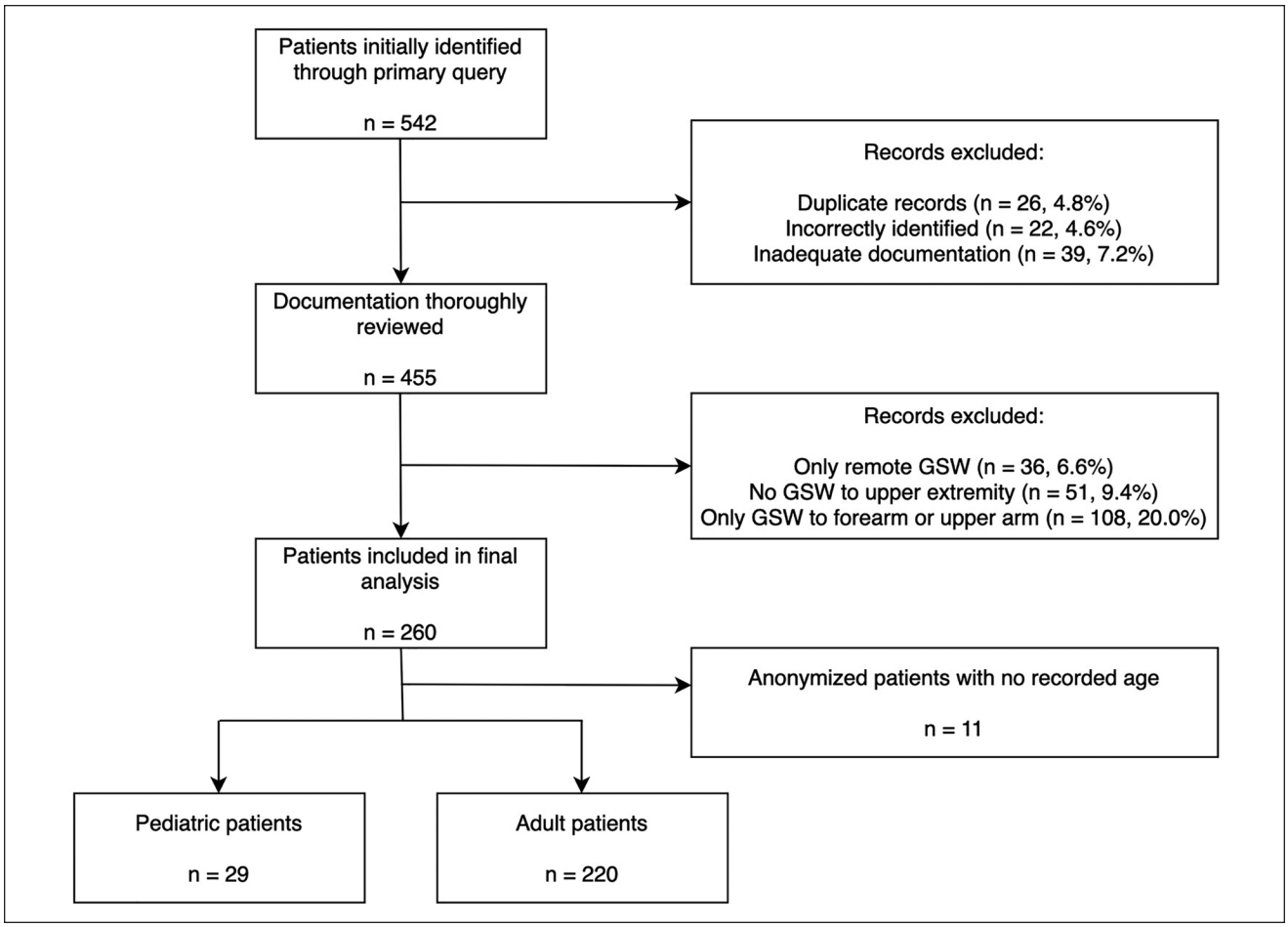

Figure 1. A flowchart of patient inclusion. After initial radiological record review, 542 victims were captured in the initial search. After applying inclusion and exclusion criteria, a total of 260 victims were included in the final analysis.
Note. This cohort comprised 29 children and 220 adult victims, as well as 11 anonymized patients who had no recorded age. GSW = gunshot wound.

formed acutely as opposed to as outpatient procedures following discharge. For the victims who were discharged for later surgery, they waited a median of 7 days before surgery. The most common method of bony fixation during surgery was with Kirschner wires, which were used for 4 (27%) children and 58 (51%) adults. There was no statistically significant difference between adult and pediatric groups for these surgical characteristics (Table 5).

Overall, 87 victims (35%) suffered a GSW to another body region in addition to their wrist or hand GSW. The lower extremity was the most likely body part to suffer a concurrent injury in both children (n = 3, 10%) and adults (n = 28, 13%). There was no statistically significant difference between children and adults in concurrent GSW distribution.

Discussion

In our center, most GSWs occurred as an isolated injury due to intentional gunfire perpetrated by someone other than the victim. This finding differs from the retrospective review of 97 victims with GSWs to the hand in which Hutchinson et al[20] reported that most injuries were self-inflicted and due to accidental discharge while cleaning or loading a firearm. This difference in shooting circumstance may be accounted for by the fact that our study was conducted in a larger metropolitan area, with higher rates of violent crime.[28]

The literature examining racial disparities in GSWs involving the wrist or hand remains sparse at this time. Although our academic center is located in a city whose population is only 45% Black,[29] 77% of the victims included in this study identified as Black. Our data agree with previous findings noted by Cook et al[25] that Black GSW victims are more likely to have been injured in assault-type scenarios. In addition, in our study, Caucasian victims were *more* likely to have intraoperatively noted neurological or vascular injury. The difference in shooting circumstances (shot by others vs shot by self) between these 2 cohorts may partially account for this difference in the rate of neurological or vascular injury.

Table 1. Characterization of Patient Demographics.

Variable	Pediatric patients n = 29 n (%)	Adult patients n = 220 n (%)	*P* value
Age, y			
Mean ± SD	13.7 ± 4.6	33.2 ± 13.9	
Median	15	28	
Range	2-17	18-83	
Sex			.73
Male	26 (90)	201 (91)	
Female	3 (10)	19 (9)	
Race/Ethnicity			.28
Black	25 (86)	164 (75)	
Native American	0 (0.0)	1 (1)	
White	3 (10)	51 (23)	
Unknown	0 (0.0)	4 (2)	
Insurance			
Medicaid	5 (17)	24 (11)	.20
Medicare	0 (0.0)	9 (4)	
Other government assistance	1 (3)	10 (5)	
Private	12 (41)	56 (26)	
Uninsured	11 (38)	121 (55)	
Zip code classification			.80
Urban	27 (93)	192 (87)	
Rural	2 (7)	19 (9)	
Unknown	0 (0)	9 (4)	
Hand dominance			.28
Right	16 (55)	145 (66)	
Left	4 (14)	13 (6)	
Ambidextrous	0 (0)	1 (1)	
Unknown	9 (31)	61 (28)	

Table 2. Characterization of Gunshot Wounds by Race.

Variable	Caucasian n = 54 n (%)	Black n = 200 n (%)	*P* value
Insurance type			<.01
Public	10 (19)	41 (16)	
Private	25 (46)	44 (22)	
Uninsured	19 (35)	115 (58)	
Shooter			<.01
Self	13 (24)	24 (12)	
Other	32 (59)	126 (63)	
Unknown	9 (17)	50 (25)	
Conflict type			<.01
Intentional	14 (26)	100 (50)	
Accidental	33 (61)	26 (13)	
Unknown	7 (13)	74 (37)	
Intraoperative injury noted			
Nerve	11 (20)	14 (7)	<.01
Vascular	10 (19)	9 (5)	<.01

More than a third of the victims in our study suffered GSWs to multiple body regions. In a 10-year follow-up study of 62 victims with complex GSWs to the hand and wrist treated surgically, Pereira et al[10] noted that, in 97% of victims, the GSW to the hand or wrist was part of a multiple GSW assault. The study by Pereira et al differed from ours, in that it reported on patients admitted to a West Coast level 1 trauma center during an earlier time period (1997-2007) with different sociodemographic characteristics (43% Hispanic, 31% Black, 21% Caucasian in theirs vs 76% Black, 22% Caucasian in ours). However, the high rate of multiple concomitant injuries in both studies underscores the importance of a thorough tertiary examination and a high index of suspicion for additional injuries in evaluating patients with GSWs to the hand and wrist.

Surgery for hand and wrist GSWs involves a balance of promoting bony healing to restore stability while preserving motion to prevent stiffness. Complex GSWs of the hand and wrist involve multiple tissue types; when performing surgery for complex GSWs, the surgeon must prioritize which tissues to repair or reconstruct and the urgency with which these must be performed.[30] In a 2003 review on gunshots to the hand and upper extremity, Wilson proposed that bone and joint are the top operative priority to restore stability, whereas blood supply is the most critical to restore urgently to mitigate the risk for necrosis.[30] It is accepted that timely definitive coverage and reconstruction may minimize infection risk, expedite hospital stay, and enable quick rehabilitation initiation for better functional outcomes.[9,18] In our cohort, more than half of the victims were treated with surgery with roughly half undergoing surgery acutely. The vast majority of victims underwent a single surgery only, and Kirschner wires were the most common method of fixation (48%). These figures are comparable to those noted elsewhere in the literature.[9,20,21,24,31] In their analysis of 77 patients with ballistic fractures of the hand and wrist, Ghareeb et al[21] noted use of Kirschner wires in 41% of cases, citing their technical ease and ability to retain bone length as reasons for common use.

Previous researchers have reported high rates of return of function in nerve injuries associated with upper extremity trauma.[32,33] These findings remain true in nerve injuries caused by GSWs or explosives; in patients with upper extremity nerve palsy following a low-velocity GSW, Omer[32] described a spontaneous nerve recovery rate of 69%. In our study, nearly a quarter of the victims (23%) had physical examination findings consistent with nerve injury, whereas only 10% of patients undergoing surgery had nerve discontinuity identified intraoperatively, suggesting that a

Table 3. Details of Shooting.

Variable	Pediatric patients n = 29 n (%)	Adult patients n = 220 n (%)	*P* value
Shooter			.65
Self	6 (21)	51 (23)	
Other	18 (62)	114 (52)	
Unknown	5 (17)	55 (25)	
Conflict type			.17
Intentional	17 (59)	93 (42)	
Accidental	7 (24)	53 (24)	
Unknown	5 (17)	74 (34)	
Urine drug screen			.37
Negative	4 (14)	59 (27)	
Ethanol	1 (3)	21 (10)	
Cocaine	0 (0)	7 (3)	
Cannabinoids	1 (3)	4 (2)	
Fentanyl	0 (0)	1 (1)	
Phencyclidine	0 (0)	1 (1)	
Polysubstance	0 (0)	5 (2)	
No test administered	23 (79)	122 (56)	

Table 4. Characterization of GSW Injuries.

Variable	Pediatric patients n = 29 n (%)	Adult patients n = 220 n (%)	*P* value
Bones fractured			
Carpal bones	2 (7)	23 (11)	.75
Metacarpal	9 (31)	84 (38)	.46
Proximal phalanges	7 (24)	56 (26)	.88
Middle phalanges	1 (3)	19 (9)	.48
Distal phalanges	2 (7)	17 (8)	1.0
None	10 (35)	56 (26)	.30
Nerve injury			.82
Clinically	5 (17)	52 (24)	
Surgically	3 (10)	24 (11)	
None	20 (69)	140 (64)	
Unknown	1 (3)	4 (2)	
Vascular injury			.79
Clinically	0 (0)	3 (1)	
Surgically	2 (7)	18 (8)	
None	27 (93)	195 (89)	
Unknown	0 (0)	4 (2)	
Concurrent GSWs			
Face	2 (7)	15 (7)	1.0
Neck	0 (0)	4 (2)	1.0
Chest	0 (0)	11 (5)	.37
Abdomen	1 (3)	17 (8)	.70
Back	0 (0)	7 (3)	1.0
Upper arm	0 (0)	15 (7)	.23
Forearm	2 (7)	5 (2)	.19
Lower extremity	3 (10)	28 (13)	1.0
Perineum	0 (0)	8 (4)	.60
None	21 (72)	141 (64)	.38

Note. GSW = gunshot wound.

substantial proportion of nerve injuries detected on clinical examination may be neurapraxic and thus not require surgical exploration.

This study has several limitations. First, our study was retrospective in nature and relied on medical record review and is therefore subject to information bias. Second, our study did not aim to provide any evidence regarding patient follow-up or outcomes following these injuries. Third, the patients analyzed may not perfectly reflect the population of gunshot victims in our region. There is another level 1 trauma center in our region, and potential biases in presentation to, or emergency transport to the centers could skew who presents to our center. Finally, given the fact that violent crimes vary significantly across different cities,[28] the data collected at our center may not align with or be representative of GSW-related injury nationwide.

Although largely descriptive, strengths of this study include the large number of victims included. This study is also unique, in that it includes both children and adults. Our subgroup analyses did not detect any significant differences between children and adults with respect to epidemiological data, shooting circumstances, bony or soft tissue injury, additional injuries, or fixation strategy. Importantly, most of the children in our study sustained injuries as a result of intentional violence. This finding is in agreement with previously reported data[34] and may inform future policy aimed at minimizing the morbidity incurred by GSWs in adult and pediatric populations.

As gun violence deaths continue to climb in the United States,[1] firearm access has remained a hotly contested public health issue. In recent years, medical organizations have increasingly begun to take a public stand against the status quo regarding gun violence, calling for action to reduce the health consequences of firearms. In 2015, the American College of Surgeons (ACS), along with other health professional organizations and the American Bar Association, issued a statement urging lawmakers to address firearm-related injury and death in the United States.[35] In 2019, the ACS—along with the American Academy of Orthopaedic Surgeons, the American Society for Surgery of the Hand, and 41 other major medical organizations—went further, issuing a consensus statement that named firearm injury as a public health crisis.[36] This statement called for a comprehensive public health approach to reduce death and disability from firearms and

Table 5. Surgical Details.

Variable	Pediatric patients n = 29 n (%)	Adult patients n = 220 n (%)	*P* value
Surgery performed			1.0
Yes	15 (52)	114 (52)	
No	14 (48)	106 (48)	
Surgery circumstance			.53
Discharged for later surgery	6 (40)	50 (44)	
Immediate surgery	9 (60)	54 (47)	
Inpatient for other injuries	0 (0)	10 (9)	
No. of surgeries			.34
1	10 (67)	94 (81)	
2	3 (20)	18 (16)	
3	1 (7)	2 (2)	
4+	1 (7)	2 (2)	
Method of fixation			.08
Kirschner wires	4 (27)	58 (51)	
Plate	2 (13)	17 (15)	
External fixator	1 (7)	4 (4)	
Screws	0 (0)	1 (1)	
Multiple methods	2 (13)	1 (1)	
None	6 (40)	33 (29)	

again asked for further research to better identify the people most at risk of firearm injury, as well as urging health care systems to engage communities to better understand the causes of violence.[36] Our data speak to this need as most GSWs treated were intentional interpersonal violence. Moving forward, further research and educational programs targeted at communities at risk of firearm violence may play an important role in shaping future initiatives to reduce firearm injury.

Authors' Note

Investigation was performed at Washington University School of Medicine, Barnes-Jewish Hospital, and St. Louis Children's Hospital.

Ethical Approval

The study was performed with institutional review board approval.

Statement of Human and Animal Rights

This study did not involve any human and/or animal experimentation.

Statement of Informed Consent

There are no identifying personal details in this study; informed consent was not required for any of the included patients.

Declaration of Conflicting Interests

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