Wounding Patterns Based on Firearm Type in Civilian Public Mass Shootings in the United States

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BACKGROUND: There are no studies correlating wounding pattern or probability of death based on firearm type used in civilian public mass shooting (CPMS) events. Previous studies on non-CPMS events found that handguns are more lethal than rifles. We hypothesized that CPMS events associated with a handgun are also more lethal than those associated with a rifle.

STUDY DESIGN: A retrospective study of autopsy reports from CPMS events was performed; CPMS was defined using the FBI and the Congressional Research Service definition. Site(s) of injury, site(s) of fatal injury, and presence of potentially preventable death (PPD) were determined independently by each author and cross-referenced to firearm type used.

RESULTS: Autopsy reports of 232 victims from 23 events were reviewed. Seventy-three victims (31%) were shot by handguns, 105 (45%) by rifles, 22 (9%) by shotguns, and 32 (14%) by multiple firearms. Events using a handgun were associated with a higher percentage killed, and events using a rifle were associated with more people shot, although neither difference reached statistical significance. Victims shot by handguns had the highest percentage of having more than 1 fatal wound (26%); those shot by rifle had the lowest percentage (2%) ($p = 0.003$). Thirty-eight victims (16%) were judged to have had a PPD. The probability of having a PPD was lowest for events involving a handgun (4%) and highest for events involving a rifle (23%) ($p = 0.002$). Wounding with a handgun was significantly associated with brain ($p = 0.007$) and cardiac injury ($p = 0.03$).

CONCLUSIONS: Civilian public mass shooting events with a handgun are more lethal than those associated with use of a rifle. (J Am Coll Surg 2019;228:228–234. © 2018 by the American College of Surgeons. Published by Elsevier Inc. All rights reserved.)

The frequency of civilian public mass shooting (CPMS) events remains a significant public health concern across the US.[1,2] The only study evaluating the case fatality rate (CFR), defined as the number of persons killed divided by the number of persons killed and wounded after CPMS events, found a CFR of approximately 45%, a rate that is 2.5 times higher than that reported after non-CPMS gun-related violence and 4.5 times higher than that reported by the US military in combat.[3-5]

Two related key differences between handguns, shotguns, and rifles (not including shotgun) include velocity of the fired projectile and accuracy. Bullets cause tissue injury by transferring their kinetic energy into their target. Kinetic energy is described by the equation: $KE = 1/2MV^2$, where M is the mass of the projectile and V is its velocity. Given that the muzzle velocity of a projectile leaving a rifle is 1,500 to 4,000 feet/second, and the muzzle velocity of a projectile leaving a handgun is 700 to 1,500 feet/second, it makes sense to assume that CPMS events associated with rifles would be more lethal than those

CME questions for this article available at http://jacscme.facs.org

Disclosure Information: Authors have nothing to disclose. Timothy J Eberlein, Editor-in-Chief, has nothing to disclose.

Received September 27, 2018; Revised November 17, 2018; Accepted November 26, 2018.

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https://doi.org/10.1016/j.jamcollsurg.2018.11.014
ISSN 1072-7515/18

Abbreviations and Acronyms

CFR = case fatality rate
CPMS = civilian public mass shooting
PPD = potentially preventable death

associated with handguns.[6] Also, the higher muzzle velocity associated with rifles results in much greater accuracy and therefore, range to target. However, previous studies on non-CPMS gunshot wounds have found that penetrating trauma from handguns is associated with more gunshot wounds per victim, a higher likelihood of injuries to vital organs, and a higher CFR.[7,8] There have been no studies to date examining the relationship between the type of firearm used, wounding characteristics, and case fatality rate in CPMS events. This information could be vital in determining public health policy as well as response strategy regarding CPMS events.

We previously performed a retrospective study evaluating wounding patterns and causes of death in 27 CPMS events (under review). This article is a sub-analysis of the same dataset. We hypothesized that, as with non-CPMS events, CPMS events carried out with a handgun are associated with both more gunshot wounds and more severe wounds than CPMS events associated with a rifle.

METHODS

Civilian public mass shooting events were identified from the New York Police Department 2016 Active Shooter Summary Report cross-referenced with the US Federal Bureau of Investigation (FBI) report of active shooter events from 2000 to 2016.[2,9] Events were defined as any incident that met the following 3 criteria: incidents occurring in relatively public places involving 4 or more deaths, not including the shooter(s); gunmen who select victims indiscriminately; and the violence in these cases is not meant to be a means to an end, such as burglary.[1,10] Only patients who underwent a full autopsy and for whom data regarding firearm type were available were included in this study. Firearms were categorized as handgun, rifle (any long barrel firearm except shotgun), and shotgun based on information available in the autopsy report. The George Washington University Institutional Review Board deemed this study to be exempt from their review.

Each autopsy report was independently reviewed by a multidisciplinary panel of experts consisting of 4 trauma surgeons, a forensic pathologist, a coroner, an emergency medicine physician, and a critical care/advanced practice paramedic. Body region of wounding, number of gunshot wounds, organ(s) critically injured, and firearm(s) used were abstracted directly from autopsy reports provided by medical examiners. Body regions were defined as head (including face), neck, chest/upper back (defined as above the costal margin or above the tip of the scapula), abdomen/lower back (including groin and buttocks), and extremity. Each wound on the skin was counted as a separate gunshot wound. For example, a patient who had a gunshot penetration to the chest and back was counted as having 2 gunshot wounds.

The incidence of potentially preventable death (PPD) was determined by consensus of the author group (ERS, BRHR, GS, SG, BS), with the criteria for PPD being defined as pre-hospital care available within 10 minutes of injury and trauma center care within 1 hour, as recommended by current Pre-Hospital Trauma Life Support recommendations.[11] Wounds were considered fatal if they involved both cerebral hemispheres, the mid-brain or brainstem, cervical spinal cord at or above C5, heart, any nonextremity major vascular structure, or multiple solid organs. Injuries were considered potentially survivable if they involved vascular structures in the extremities, or torso injuries without the presence of major vascular or multivisceral injuries. In instances in which 20% or more of the author group disagreed on an outcome, a fourth trauma surgeon (JE), who had not previously reviewed the autopsies, served as the final determinant of the outcome in question.

Proportional data were analyzed using Fisher's exact test, and continuous data were analyzed using a 2-tailed Student's *t*-test. Case fatality rate was determined for each event using information obtained from the aforementioned databases and verified using an internet search of the public reports of each event. We then compared the total number of people shot to the number of people killed by firearm type by event. Next, using CPMS event as the unit of analysis, we examined the association of case fatality rate with percent of victims shot by firearm type using Pearson correlation coefficients. Using patients as the unit of analysis, Fishers exact test was used to examine the association of firearm and PPD rate with organ and with body region. Data were analyzed using SPSS 25 for Windows (IBM SPSS Statistics) and SAS (version 9.4), with $p < 0.05$ considered significant.

RESULTS

Information regarding both autopsy and firearm type was available for 23 of 27 CPMS events involving 232 of 247 total victims (Table 1). Seventy-three patients (31%) were shot using handguns, 105 (45%) by rifles, 22 (9%) by shotguns, and 32 (14%) by multiple firearms. The total number of people shot with a rifle was 128, which included 23 shot with multiple firearms. Of these, 104 (81%) were shot using an assault rifle.

Table 1. Case Fatality Rate by Incident and Firearm Type

			People shot by firearm, n			
Event location	**Year**	**Case fatality rate, %**	**Handgun**	**Shotgun**	**Rifle**	**Multiple**
San Diego, CA	1984	53.7	8	6	0	8
Edmond, OK	1986	71.4	15	0	0	0
Jonesboro, AR	1998	33.3	1	0	1	3
Jefferson County, CO	1999	35.1	3	5	0	6
Melrose Park, IL	2001	50.0	3	0	0	1
South Bend, IN	2002	66.6	0	0	0	4
Chicago, IL	2003	100.0	7	0	0	0
Sawyer County, WI	2004	66.0	0	0	6	0
Lancaster, PA	2006	44.4	0	5	0	0
Crandon, WI	2007	85.7	7	0	0	0
Colorado Springs, CO	2007	50	0	0	5	0
Dekalb, IL	2008	19.2	3	0	0	1
Carthage, NC	2009	72.7	0	8	0	0
Hialeah, FL	2010	57.1	4	0	0	0
Tucson, AZ	2011	31.6	6	0	0	0
Seal Beach, CA	2011	88.9	7	0	0	1
Copley Township, OH	2011	87.5	8	0	0	0
Oakland, CA	2012	70.0	7	0	0	0
Seattle, WA	2012	83.3	3	1	0	1
Oak Creek, WI	2012	60	0	0	0	7
Santa Monica, CA	2013	55.6	5	0	1	0
Orlando, FL	2016	48.0	0	0	49	0
Las Vegas, NV	2017	10.6	0	0	58	0

Case fatality rate = number of persons killed/(number of persons killed + injured).

The mean case fatality rate in the overall cohort was 0.57 ± 0.23. The case fatality rate by firearm type was 0.63 for shotgun (2 events), 0.72 for handgun (7 events), and 0.19 for rifle (4 events) ($p = 0.10$ for rifle vs handgun and $p = 0.52$ for rifle vs shotgun). Because the Route 91 shooting in Las Vegas involved a very large number of patients, it served as an outlier for the CFR related to rifle shootings. We therefore also analyzed the CFR related to rifle shootings without this event; the CFR in this instance was 0.49. Events with higher rates of handgun use had a strong trend toward higher percentages killed. The Pearson correlations between the percent shot with each firearm and the case fatality rate were $r = 0.40$ (95% CI -0.01 to 0.70; $p = 0.06$) for handgun; $r = -0.01$ (95% CI -0.42 to 0.41; $p = 0.97$) for shotgun; $r = -0.28$ (95% CI -0.62 to 0.14; $p = 0.19$) for rifle; and $r = -0.22$ (95% CI -0.58 to 0.21; $p = 0.32$) for multiple firearms. However, when comparing events carried out with only 1 firearm type, we found that the average number of people shot was higher in events involving a rifle. The average (standard deviation) numbers of people shot in rifle-, handgun-, and shotgun-associated events were 135 (SD 198), 9 (SD 0.6), and 8 (SD 5), respectively. Excluding the Route 91 shooting resulted in a decrease in the average number of people shot in rifle-associated events to 39 (SD 56). None of these differences were statistically significantly.

One hundred ninety-five patients (84%) had a single fatal organ injury and 37 (16%) had 2 or more fatal organ injuries. Sixty percent of victims shot with a handgun had more than 1 gunshot wound, as compared with 16% who were shot with a rifle. There was a strong relationship between the number of surface gunshot wounds and number of fatal organ injuries (Spearman $r = 0.33$; $p < 0.0001$). The percentages of patients with 2 or more fatal organ injuries were 0%, 12%, 10%, 16%, 18%, and 32%, as the number of total wounds increased from 1 through 6 or more, respectively. People shot using handguns had the highest percentage of having more than 1 fatal organ injury (26%); those shot by rifle had the lowest percentage (2%) ($p = 0.003$). Only 16% of persons shot with a shotgun had 2 or more fatal organ injuries.

We examined the location of wounds on the body based on firearm type. We found that the mean number

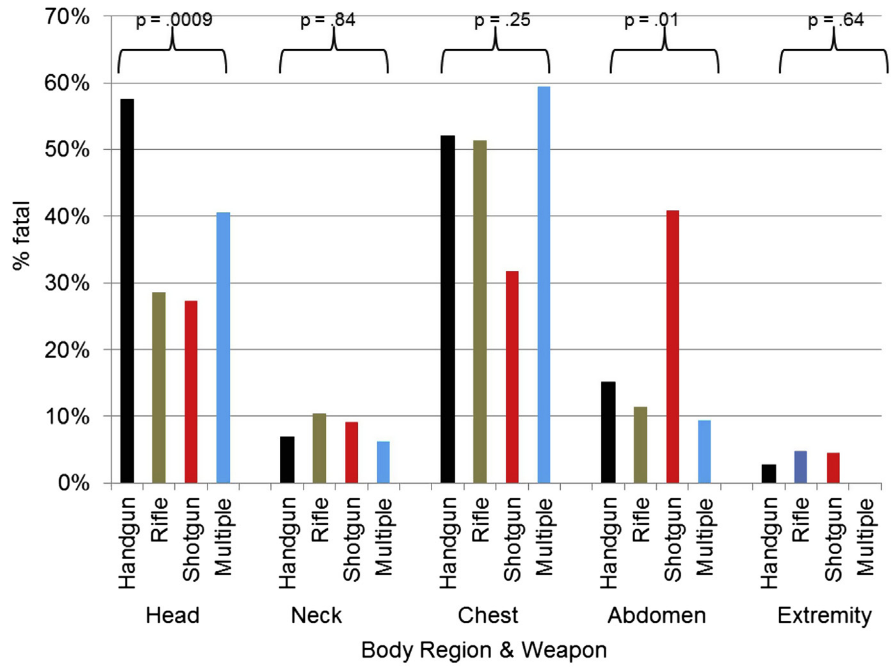

Figure 1. Percentage of people shot by firearm type in each body region.

of wounds varied significantly by body area, with chest/upper back (mean = 1.3 [95% CI 1.1 to 1.5] wounds) and extremities (mean = 1.5 [95% CI 1.2 to 1.8] wounds) having significantly more wounds than head (mean = 0.7 [95% CI 0.6 to 0.9] wounds), abdomen/low back (mean = 0.8 [95% CI 0.6 to 0.9] wounds), or neck (mean = 0.2 [95% CI 0.1 to 0.2] wounds) (all $p < 0.0001$). However, the overall pattern of number of wounds per body area did not differ significantly with respect to firearm type ($p = 0.44$)

Next, we examined the location of fatal wounding based on firearm type. Whereas fatal injuries to the chest/upper back remained prevalent, fatal injury to an extremity was rare. One hundred eighteen (51%) patients had fatal chest or upper back wounds, 91 (39%) patients had fatal wounds to the head, 35 (15%) patients had fatal abdominal wounds, 20 (9%) patients had fatal wounds to the neck, and 8 (3%) patients had fatal extremity wounds. Firearm type was significantly associated with having fatal wounds to the head ($p = 0.0009$) and abdomen/low back ($p = 0.01$), but not to the neck ($p = 0.84$), chest/upper back ($p = 0.25$), or extremities ($p = 0.64$) (Fig. 1). Among those shot by shotgun, rifle, multiple firearms, or handgun, the percentages with fatal head wounds were 27%, 29%, 41%, and 58%, respectively, and the percentages with fatal abdominal wounds were 41%, 11%, 9%, and 15%, respectively. Therefore, fatal head wounds were most likely when shot with a handgun; fatal abdominal wounds were most likely when shot with a shotgun.

We then examined the association between actual organ fatally injured and firearm type. The organ injury that most often resulted in death was the brain (40%) followed by lung (32%). There was a significant association between firearm type and injury to the brain ($p = 0.007$) and heart ($p = 0.027$) (Table 2). Fifty-six percent and 40% of persons shot with a handgun sustained a fatal injury to the brain and heart, respectively.

Thirty-eight patients (16%) had potentially preventable death (PPD). For multiple firearms, rifle, shotgun, and handgun, the PPD rates were 22%, 23%, 18%, and 4%, respectively ($p = 0.007$). Therefore, those shot with handguns were significantly less likely to have PPD than those shot with other firearms. Among people with PPD, 63% were shot by rifle vs 8% by handgun; for non-PPD cases, 42% were shot by rifle vs 36% by handgun. Paradoxically, those shot with a rifle were significantly more likely to have a PPD than those shot with other firearms (23% vs 11%; $p = 0.02$). The top 2 organs associated with having a PPD were the lung (31%) and spinal cord (25%) (Table 2).

DISCUSSION

The incidence of CPMS continues to rise such that the medical community now considers this to be a public health crisis.[12,13] As such, a comprehensive approach to understanding these events is necessary to mitigate the risk of death. Unfortunately, there are very few studies evaluating specific details related to CPMS events. Our group has

Table 2. Organs Injured by Firearm Type

Organ	Cases, n (%)	Handgun (n = 73), %	Rifle (n = 105), %	Shotgun (n = 22), %	Multiple firearms (n = 32), %	Fisher Exact test p	PPD, n (%)
Brain	92 (40)	56	32	27	34	0.007*	2 (2)†
Lung	74 (32)	30	32	23	41	0.57	23 (31)†
Heart	66 (28)	40	20	23	34	0.027*	0 (0)†
Liver	61 (26)	27	21	32	38	0.25	8 (13)
Thoracic aorta	41 (18)	21	20	9	9	0.38	0 (0)
Spinal cord	32 (14)	10	18	9	13	0.41	8 (25)
Pulmonary hilum	16 (7)	8	4	14	9	0.21	1 (6)
Renal hilum	17 (7)	4	8	18	6	0.18	1 (6)
Abdominal aorta	12 (5)	4	4	14	6	0.25	0 (0)
Spleen	12 (5)	5	6	9	0	0.45	2 (17)
Carotid	13 (6)	4	7	5	6	0.89	1 (8)
Trachea	9 (4)	8	2	0	3	0.16	0 (0)
Subclavian artery	6 (3)	1	2	5	6	0.31	3 (50)
IVC	5 (2)	1	2	9	0	0.15	0 (0)
SVC	4 (2)	0	2	9	0	0.07	0 (0)
Iliac vein‡	1	1	0	0	0	0.55	0 (0)

Column 2 shows number and percent of cases with injury to each organ. Columns 3 to 6 show percent of cases by firearm type with injuries to each organ. For example, 40% of cases had brain injuries, and 56% of those shot by handgun had brain injuries. The p value in column 7 is for the association between firearm and organ. For example, injuries to the brain and heart varied significantly by firearm, but injuries to the lung and other organs did not. Column 8 shows n (% of those shot in each organ) who had a PPD. The associated p value indicates whether the PPD rate for each organ differed from that of other organs combined. For example, only 2% of those with brain injury had a PPD, which is significantly less than the combined average (which was 16% PPD).
*Significant.
†$p < 0.0001$.
‡There were no wounds to iliac artery in this sample.
IVC, inferior vena cava; PPD, potentially preventable death; SVC, superior vena cava.

published 2 previous studies,[3,14] both of which found a high case fatality rate and also a high PPD rate after CPMS, but neither these studies nor any other study in the medical literature has evaluated wounding characteristics and PPD as a function of the type of firearm used in CPMS events. This study addressed this shortcoming and found that, as with homicide in non-CPMS events, the handgun was the most commonly used firearm in the CPMS events studied and was associated with a greater total number of wounds and probability of fatal organ injury, as compared with a rifle or shotgun.

In considering purely severity of tissue damage based on ballistics alone, it is correct to assume that projectiles fired from a rifle are able to cause significantly more tissue injury than those fired from a handgun or shotgun, due to the higher muzzle velocity of a projectile fired from a rifle. The higher transfer of energy results in significant cavitation of the tissues, with resultant hemorrhage.[6] However, one also has to consider the number of times a victim is shot in determining overall probability of death. Our study found that there was a significant difference in the number of gunshot wounds among CPMS victims, and that those who were shot with a handgun were almost 4 times more likely to have 3 or more wounds compared with those shot with a rifle. As would be expected, the number of gunshot wounds was directly proportional to the probability of sustaining a fatal injury to at least 1 vital organ. Therefore, as was noted in studies evaluating the impact of firearm type in non-CPMS shootings, the probability of death is higher for events involving a handgun than a rifle.

Our study found that events purely associated with a rifle resulted in a much larger number of people injured, but a smaller number of people killed. The results were not statistically different due to small sample size, but the absolute magnitude of difference between rifle- and nonrifle-associated events appeared large. We cannot account for this finding with confidence, but a possible explanation may be that rifles are likely to have a higher capacity magazine than handguns, thereby allowing the shooter to fire more rounds before needing to reload. However, our study also found that the number of gunshot wounds per patient was significantly higher in handgun-associated events, as compared with other firearm types. Again, we cannot know for certain why this difference exists, but 1 possibility is that the higher energy transfer associated with a rifle results in the victim collapsing, thereby making a second wounding of the same victim less likely. Another possibility is that it may be easier for the shooter to fire multiple rounds quickly and accurately using a handgun than a rifle, thereby increasing the probability of the victim being hit multiple times.

A previous study comparing the number of gunshot wounds between handguns and rifles found that handgun-associated events resulted in more penetrations per patient and more body regions hit per patient than events associated with a rifle.[7] It is logical that the greater number of gunshots per victim increases the lethality connected with handgun-associated events as compared with rifle-mediated events. Wounds to the brain and heart have higher fatality rates than gunshots to other organs, and these were most likely to occur when handguns were used. In total, our results suggest that CPMS events with rifles are associated with more people being shot, but the proportion of people killed is higher in handgun-associated events. However, we acknowledge that these results are based on small sample sizes and therefore need to be validated by continuing to study future events.

Our findings should draw attention to the fact that the probability of death will not decrease significantly by concentrating on laws related to gun ownership and access to a particular class of firearms. Rather, a holistic approach to all types of firearms is necessary if we are to mitigate the risk of fatal injury after CPMS events. This is similar to conclusions drawn in a seminal paper evaluating the impact of bullet caliber on probability of death.[15] Somewhat paradoxically, that study found a higher number of deaths were due to events that involved lower caliber bullets due to easier access to short-barreled 0.25 caliber handguns. The authors of that study therefore called for strategies to address these firearms in addition to high caliber, high energy rifles.

Although our study is the first report that evaluates the nature of gunshot wounds and probability of death as a function of firearm type after CPMS events, it does have several shortcomings. Most importantly, despite working with an attorney to file jurisdiction-specific Freedom of Information Act (FOIA) requests, we were able to obtain information on only 44% of CPMS identified because of state laws or local policy precluding release of autopsy information. Many state laws and local policies prohibit this type of research, so this study represents the most insightful evaluation currently possible. Second, we were unable to account for the caliber or design characteristics of bullets used because this information was rarely included in the autopsy reports. Although bullets do not have significant mass, they have variable designs that allow them to transfer their energy in order to maximize their destructive ability.[6] For example, the destructive capabilities of a hollow point or a soft-nosed bullet vs a projectile that maintains its shape are notably different, irrespective of muzzle velocity. Additionally, certain types of projectiles are more deadly in the chest and abdomen due to the greater depth of tissue, allowing the bullet to yaw significantly along a greater distance and thereby expanding the area of destruction.[6,16] Because of these variances in projectile characteristics, the subtype of bullet used may provide critical information to guide the management of a shooting victim. Next, as noted above, comparisons of events using only 1 firearm type are limited by small sample size. The risk for selection bias does exist by the nature of this work in that we examined only persons who died. The determination of PPD is subjective by its nature. Our author group represents a multidisciplinary panel of experts, including a forensic pathologist, and used the same processes advocated by the American College of Surgeons Committee on Trauma in assessing the quality of care rendered by trauma centers[17] in order to try to maintain as objective an assessment of PPD as possible. Last, we were not able to take into account transport modality, ground vs air, in determining PPD based on the dataset we had.

CONCLUSIONS

Civilian public mass shootings associated with use of a handgun are more lethal than those associated with use of a rifle, which are associated with more people shot. Because the overall case fatality rate in CPMS is significantly higher than in non-CPMS shooting events, a holistic approach to gun legislation that addresses all types of firearms is necessary if we are to have a significant impact on mortality in CPMS events.

Author Contributions

Study conception and design: Sarani, Shapiro, Smith

Acquisition of data: Sarani, Estroff, Robinson, Shapiro, Gondek, Mitchell, Smith

Analysis and interpretation of data: Sarani, Hendrix, Estroff, Amdur, Robinson, Shapiro, Gondek, Mitchell, Smith

Drafting of manuscript: Sarani, Hendrix, Matecki, Estroff, Amdur, Robinson, Shapiro, Gondek, Mitchell, Smith

Critical revision: Sarani, Hendrix, Estroff, Robinson, Shapiro, Smith

Acknowledgment: The authors would like to thank and acknowledge Ciara Malone, JD for her assistance in sending Freedom of Information Act requests to each jurisdiction for autopsy reports.

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