Incidence and Cause of Potentially Preventable Death after Civilian Public Mass Shooting in the US

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BACKGROUND: The incidence and severity of civilian public mass shooting (CPMS) events continue to rise. Understanding the wounding pattern and incidence of potentially preventable death (PPD) after CPMS is key to updating prehospital response strategy.

METHODS: A retrospective study of autopsy reports after CPMS events identified via the Federal Bureau of Investigation CPMS database from December 1999 to December 31, 2017 was performed. Sites of injury, fatal injury, and incidence of PPD were determined independently by a multidisciplinary panel composed of trauma surgery, emergency medicine, critical care paramedicine, and forensic pathology.

RESULTS: Nineteen events including 213 victims were reviewed. Mean number of gunshot wounds per victim was 4.1. Sixty-four percent of gunshots were to the head and torso. The most common cause of death was brain injury (52%). Only 12% (26 victims) were transported to the hospital and the PPD rate was 15% (32 victims). The most commonly injured organs in those with PPD were the lung (59%) and spinal cord (24%). Only 6% of PPD victims had a gunshot to a vascular structure in an extremity.

CONCLUSIONS: The PPD rate after CPMS is high and is due mostly to non-hemorrhaging chest wounds. Prehospital care strategy should focus on immediate point of wounding care by both laypersons and medical personnel, as well as rapid extrication of victims to definitive medical care. (J Am Coll Surg 2019;229:244−251. © 2019 by the American College of Surgeons. Published by Elsevier Inc. All rights reserved.)

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The rising frequency of civilian public mass shooting (CPMS) events is a significant public health concern across the US.[1-6] The need to revise traditional police/fire/emergency medical services response paradigms first gained significant support after the Columbine High School shooting in 1999 and was re-invigorated after events such as the Century 16 Movie Theater shooting in Aurora, CO and the Sandy Hook Elementary School shooting.[7] Guidelines and procedures aimed at decreasing civilian deaths after mass casualty events were developed based on medical strategies that had been implemented successfully by the military on the battlefield.[8] These strategies were centered on rapid care at or near the point of wounding.[9,10] The push for immediate medical care, starting with non-medical personnel, and for rapid extrication to definitive trauma care has been championed nationally by professional and volunteer organizations.[11,12] It is furthered by

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private and government immediate medical care training programs, such as the American College of Surgeons' Stop the Bleed training and the Federal Emergency Management Agency's Until Help Arrives program.[13,14]

To date, there have been only 2 studies evaluating the actual cause(s) of death and opportunities to mitigate the risk of death after CPMS events.[15,16] These studies found potentially preventable death (PPD) rates of 7% and 30%, but were limited by small sample sizes and number of events included in the study. The studies also demonstrated that military and civilian injuries are not analogous, as evidenced by a significantly higher probability of death associated with civilian (45%) vs military (10%) events.[17] Elucidating the pattern of injury, cause of death, and survival potential after CPMS is critical to create outcomes-based systems and process improvements.

The purpose of this project was to determine the fatal wounding characteristics after CPMS events in the US using a larger data set that includes a higher number of CPMS events. Specifically, we sought to describe the mean number of wounds sustained, cause(s) of death, and incidence and cause(s) of PPD.

METHODS

The Federal Bureau of Investigation and the Congressional Research Service define a public mass shooting as any event that meets 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 robbery.[5,18] The New York Police Department's 2016 Active Shooter Summary Report lists every active shooter event in the US since 1966.[6] This database was cross referenced with the Federal Bureau of Investigation's report of active shooter events from 2000 through 2017[19] to identify events for inclusion in the study. Not all active shooter incidents met the threshold of CPMS as defined here.

The medical examiner or coroner for CPMS events that occurred from the Columbine High School shooting in April 1999 through December 31, 2017 was contacted and autopsy records were requested under the Freedom of Information Act using jurisdiction-specific references drafted by an attorney. For events where state law precluded the direct distribution of autopsy reports, records with personal health information elements redacted were requested. Because the study used publically available records, the George Washington University IRB deemed it to be exempt.

Consistent with the approach taken by trauma surgeons in evaluating patients who have sustained gunshot injuries, each gunshot wound was counted as a separate wound. Each gunshot wound was catalogued by body region, which was 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. Special note was made about the presence of injury to junctional vascular structures (neck, axilla, and groin injuries) because these wounds might not be amenable to prehospital hemorrhage control. Only patients with a full autopsy report were included in this study. Patients who underwent a postmortem external examination only were excluded.

After all of autopsy reports were obtained, a multidisciplinary panel of 7 reviewers, including 3 trauma surgeons, 1 coroner, 1 forensic pathologist, 1 emergency medicine physician, and 1 critical care/advanced practice paramedic, reviewed each report independently. The overall injury burden was determined to be "survivable" or "non-survivable" based on expert opinion, with the criteria for survivability being defined by prehospital care available within 10 minutes of injury and definitive medical care within 1 hour, as recommended by current Prehospital Trauma Life Support guidelines.[20] Wounds were considered fatal if they involved both cerebral hemispheres, the mid-brain or brainstem, cervical spinal cord at or above C5, heart, any non-extremity major vascular structure, or multiple solid organs. Wounds were defined as potentially survivable if they involved vascular structures in the extremities, or torso injuries without the presence of major vascular or multivisceral injuries. Autopsies were additionally evaluated for evidence of survival to the hospital as defined by documented hospital-based resuscitative measures and procedures, such as central venous access, tube thoracostomy, or thoracotomy.

Differences in the number of non-fatal injuries were averaged among reviewers. In instances where the discordant rate of reviewers' assessment of survivability or cause of fatality exceeded 20%, a fourth independent trauma surgeon who had not previously reviewed the autopsies made the final determination.

Data were analyzed using SPSS for Windows, version 25 (IBM SPSS Statistics). Proportional data were analyzed using Fisher's exact test and continuous data were analyzed using a 2-tailed Student's *t*-test. Patients were excluded from determination of survivability and cause of fatal wounding in instances where there was no internal autopsy information available for review.

RESULTS

A total of 61 CPMS events were identified within the US (Fig. 1). A total of 528 people were killed and 787 people

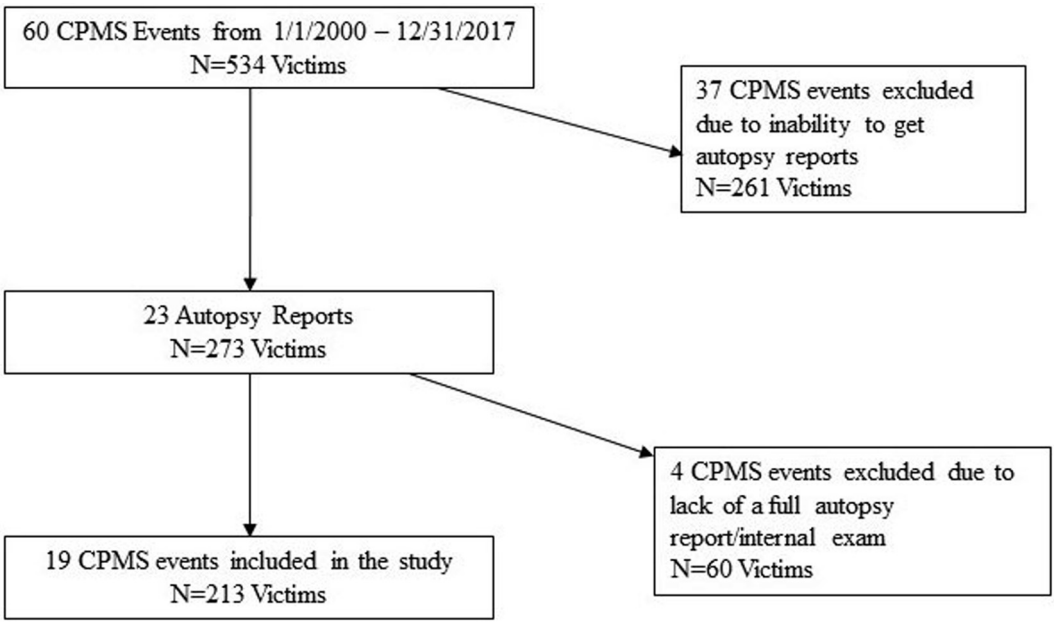

Figure 1. Flow chart of included patients. CPMS, civilian public mass shootings.

sustained non-fatal gunshots in these events, thereby giving a case fatality ratio (CFR) of 40%. We were able to obtain complete or partial autopsy results on 23 events. Of the 23 events, full autopsy reports were available for 19, which resulted in 213 deaths and constitute the study cohort (Tables 1 and 2). There was no statistical difference in the median CFR between cases that were and were not included in the study (72% [interquartile range 43% to 89%] vs 75% [interquartile range 61% to 87%]; $p = 0.39$).

Mean number of gunshot wounds per victim was 4.1 (SD 3.8), resulting in 877 total gunshot wounds and 235 fatal wounds. There was an association between number of wounds and number of fatal woundings, such that

Table 1. Civilian Public Mass Shooting Events Included in the Study

Event location, city, state	Month, year	Internal autopsy available	Autopsies reviewed, n
Jefferson, CO	April 1999	Yes	15
Melrose Park, IL	February 2001	Yes	4
South Bend, IN	March 2002	Yes	4
Chicago, IL	August 2003	Yes	7
Sawyer County, WI	November 2004	Yes	6
Lancaster, PA	October 2006	Yes	4
Colorado Springs, CO	December 2007	Yes	2
Dekalb, IL	February 2008	Yes	4
Carthage, NC	March 2009	Yes	8
Hialeah, FL	June 2010	Yes	5
Tucson, AZ	January 2011	Yes	6
Seal Beach, CA	October 2011	Yes	8
Copley Township, OH	October 2011	Yes	8
Oakland, CA	April 2012	Yes	7
Oak Creek, WI	August 2012	Yes	7
Santa Monica, CA	June 2013	Yes	6
Seattle, WA	September 2013	Yes	5
Orlando, FL	June 2016	Yes	49
Las Vegas, NV	October 2017	Yes	58

Table 2. Civilian Public Mass Shooting Events Not Included in the Study

Event location, city, state	Month, year	Fatalities, n
Wakefield, MA	December 2000	7
Houston, TX	January 2001	4
Huntsville, AL	February 2003	4
Meridian, MS	July 2003	7
Kansas City, KS	July 2004	6
Brookfield, WI	March 2005	7
Red Lake, MN	March 2005	9
Goleta, CA	January 2006	7
Seattle, WA	March 2006	6
Salt Lake City, UT	February 2007	5
Virginia Tech*	April 2007	32
Omaha, NE	December 2007	8
Kirkwood, MO*	February 2008	6
Santa Maria, CA	March 2008	4
Henderson, KY	June 2008	5
Alger, WA	September 2008	6
Geneva County, GA	March 2009	10
Oakland, CA	March 2009	4
Binghamton, NY	April 2009	13
Fort Hood, TX	November 2009	13
Lakewood, WA	November 2009	4
Manchester, CT	August 2010	8
Buffalo, NY	August 2010	4
Carson City, NV	September 2011	4
Seattle, WA	May 2012	5
Aurora, CO	July 2012	12
Minneapolis, MN	September 2012	6
Newtown, CT	December 2012	27
Herkimer, NY	March 2013	4
Federal Way, WA	April 2013	4
Navy Yard, Washington, DC*	September 2013	13
Alturas, CA	February 2014	4
Isla Vista, CA	May 2014	6
Marysville, WA	October 2014	4
Kalamazoo, MI	February 2015	6
Charleston, SC*	June 2015	9
Chattanooga, TN	July 2015	5
Roseburg, OR	October 2015	9
San Bernardino, CA	December 2015	14
Dallas, TX	July 2016	5

*Full autopsy not performed/available. Only external examination results reported. Despite a Freedom of Information Act request, local laws, policies, and/or ongoing investigations precluded the release of these autopsies.

the percent of patients with 2 or more fatal wounds increased from 1.5% to 9.8% to 22.5% as the total number of wounds increased from 1 to 2 to 3 or more. Of all the fatalities, 26 (12%) patients arrived to the hospital and had a medical procedure performed. Thirty-two (15%) victims were deemed to have had a PPD. There was a strong association between being rated as "potentially survivable" and transport to the hospital. Only 17 (9%) victims without a PPD survived to hospital arrival vs 9 (28%) of those deemed to have had potentially survivable injuries ($p = 0.002$).

Figure 2 depicts the location of all gunshot wounds, as well as the location of fatal wounds by body region. The most common body region injured was the extremity ($n = 286$), although there was a near equal number of woundings to the chest/upper back ($n = 254$). In total, 64% of all gunshot wounds ($n = 577$) were to the head and torso. The least commonly injured area was the neck. The most common sites of fatal organ injury were the head and chest/upper back, which constituted 38% and 46% of deaths, respectively. However, when comparing the probability of a fatal wound based on the incidence of injury to a particular body region (ie the CFR by body region), the head was the most likely cause of death, with 82 fatal wounds out of 159 total wounds [52%]). Combined, the CFR of gunshots to the head and torso was 211 of 557 (38%) wounds. The least likely body region to result in death, if adequate lifesaving measures were administered in a timely fashion, was the extremity, which accounted for 7 fatal woundings total or a CFR of 7 of 213 (3%). Twenty-eight (10%) patients with an extremity wound had a junctional vascular injury.

Thirty-two (15%) victims were deemed to have had potentially survivable injuries (Fig. 3). The most common injury in this cohort was a gunshot to the chest without hemothorax or major vascular injury noted on autopsy ($n = 24$ [71%]). Presumably, these patients died of tension pneumothorax. Three (9%) patients died of gunshots to the abdomen or lower back, 3 (9%) patients died of vascular injuries to the neck, and 2 (6%) patient died of a vascular injury to an extremity where a tourniquet might have been lifesaving. No PPD events related to a junctional vascular injury were found.

Concordance among reviewers was the highest for survival to the hospital, with an overall concordance rate of 209 of 213 (98%) patients. Potential survivability was concordant in 191 of 213 (90%) cases. Location of fatal wounds was concordant in 172 of 213 (81%) cases.

DISCUSSION

This study represents the third, and largest, analysis of the autopsies of victims killed in CPMS events in an effort to define the overall wounding pattern, the fatal wounding

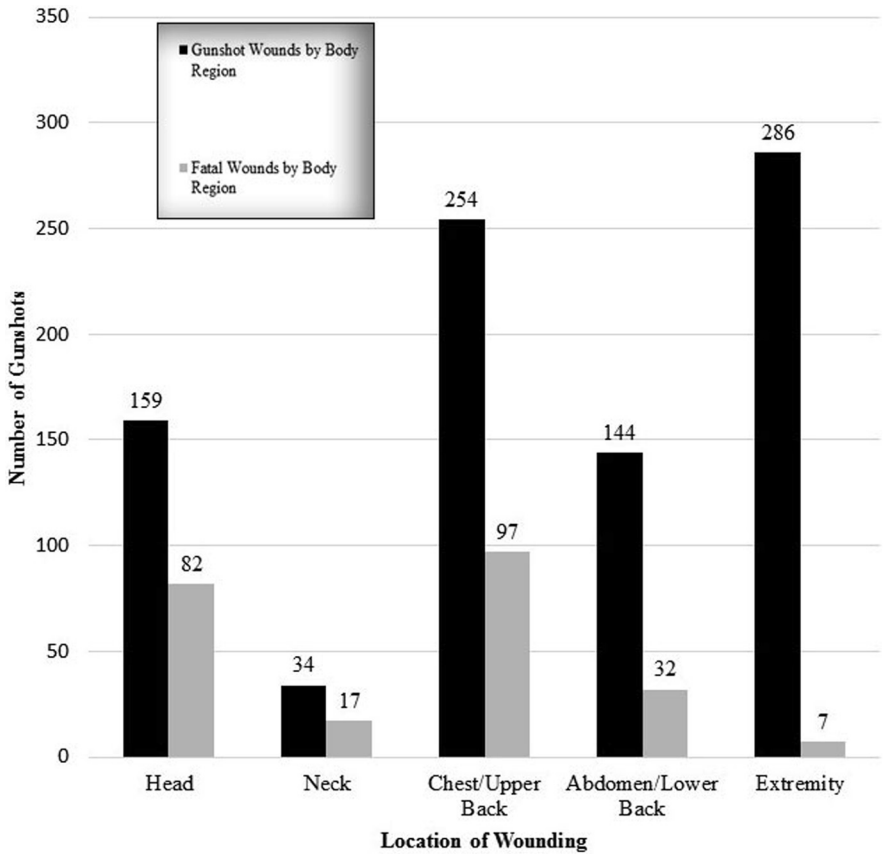

Figure 2. Total and fatal gunshot wounds by body region (n = 213).

pattern, and the exact cause of death in those that were killed. Consistent with past studies, the study found high CFR and PPD rates, the latter being mostly due to injuries to the chest and abdomen. The findings suggest that rapid extrication of victims and delivery to definitive medical care represents the best strategy to mitigate PPD after CPMS events.

The lessons learned from recent military conflicts have provided civilian-based prehospital providers a rudimentary infrastructure for emergency medical response after CPMS events. However, the civilian community differs from the military community in terms of great variability in baseline health, age, jursidictional scope of practice, and resource availability, as well as type of armament used and lack of protective body armor. As such, civilian guidance based solely on military data is imperfect. It is our hope that this article will inform policy makers and medical directors of the changes needed in prehospital response strategies to mitigate PPD rates after CPMS events.

To improve survival after CPMS events, the medical priorities to decrease PPD at or near the point of wounding must be delineated. We found that pneumothorax from gunshot wounds to the chest accounts for the largest proportion of PPD after CPMS, and a focus on immediate treatment of these injuries must be considered. Penetrating trauma that results in external exsanguinating hemorrhage remains an easily treatable cause of preventable death and the public is being appropriately trained on simple hemorrhage-control techniques via the programs mentioned previously. However, our findings of a 6% (2 of 32) incidence of vascular injury amenable to external hemorrhage control vs the 59% (20 of 34) incidence of non-vascular lung injury highlight the need for stabilizing measures by trained prehospital personnel. Needle decompression of the pleural space is not a skill taught to laypersons; however, it is a procedure that is within a paramedic's training and scope of practice. A strategy that stresses a combined approach between law enforcement and prehospital personnel to allow rapid access to victims can lower the PPD rate significantly. In addition, our finding that 26% of victims with PPD arrived to the hospital underscores the need for more rapid extrication and transportation of these individuals to definitive care. A retrospective study of 180 gunshot victims in Philadelphia found that the probability of

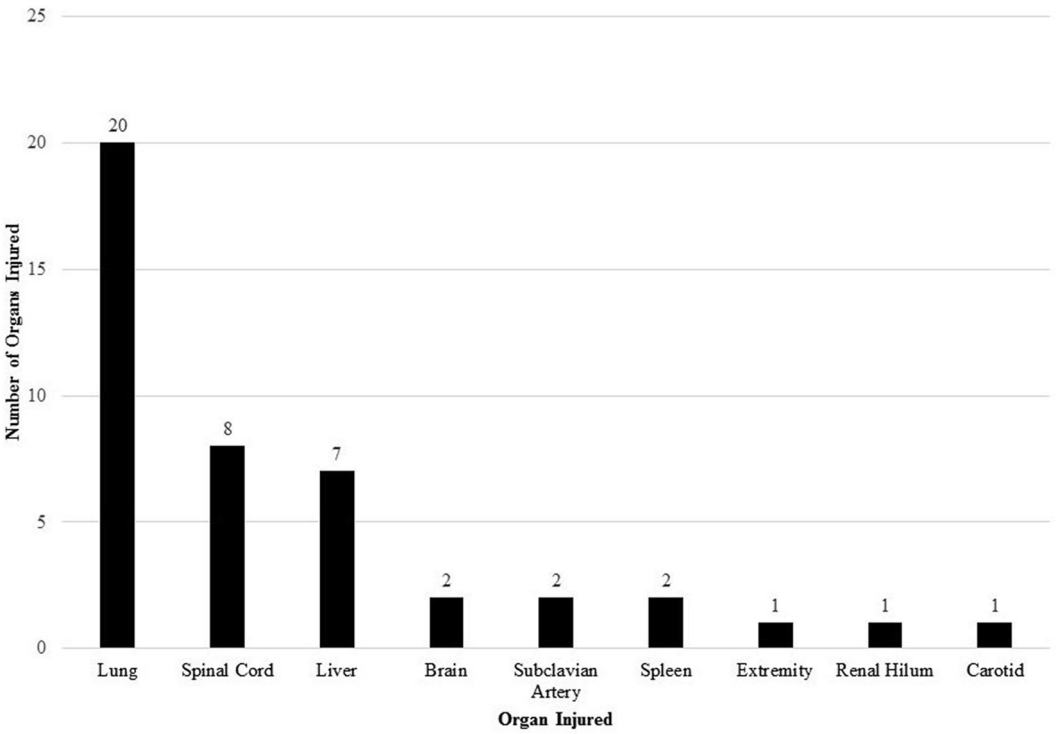

Figure 3. Organs injured in patients with a potentially preventable death (n = 34).

survival was 2.6 times higher in those transported to the hospital by police or private vehicle compared with emergency medical services. The authors suggest that this is due to more expeditious transport to a trauma center and call for a "scoop and run."[21] A similar strategy should be studied in victims of CPMS events, taking into account the different tactical environments that are inherent in these events.

Intra-abdominal bleeding constituted 10 of 34 (29%) PPDs. To address these injuries, remote damage-control principles should be initiated in the field, with an emphasis on minimizing crystalloid use, preventing hypothermia, and aggressively addressing the intrinsic coagulopathy of trauma in those with an identified high-risk wounding pattern. Although pharmacologic agents, such as tranexamic acid, are easily initiated in the field, the effects of blood loss are best treated by replacing blood and early infusion of plasma.[22,23] This goal necessitates rapid, coordinated extrication of the victim from the area of danger, followed by field initiation of blood product transfusion and transport to definitive medical care. Prehospital plasma transfusion can be most beneficial in instances where there is a delay to delivery of definitive medical care, such as in a rural setting or when rapid transport is not possible, as it was not found to be beneficial in a study involving trauma victims in an urban setting with short transport times.[24] Additional research is needed to develop the policies and procedures to initiate damage-control resuscitation earlier in the chain of care.

Although the incidence of fatal exsanguination from extremity wounds after CPMS is low, tourniquets and other external hemorrhage-control efforts are simple, effective, inexpensive, and low risk. Training civilians in tourniquet use is valuable to improving survival for those reasons and initiatives like the Stop the Bleed program represent an excellent foundation to empower laypersons to become first care providers.[25] Given that we only examined victims that died, our study's design does not allow us to know how many lives were saved through use of hemorrhage-control techniques taught to civilian bystanders. However, to have the greatest effect on survival, these efforts must be augmented by simple additional training and an overall response strategy to address all causes of preventable death in a rapid, coordinated, and efficient manner that is focused on rapid extrication of the victim from the scene and rapid transport to definitive medical care.

This study also points out one of the biggest obstacles to performing research on firearm-related injuries—laws that preclude this type of research. Despite engaging with an attorney to file jurisdiction-specific Freedom of Information Act requests for redacted reports with no

personal health information, we were only able to obtain full autopsy information on 32% of events due to many state and local laws and/or ongoing investigations that precluded release of this information. There is no way to improve this sampling without changing various state laws and local policies, and we call on legislators and policy makers to do so to allow for more robust research. This also raises the possibility of sampling bias in our results. However, there was no difference in the CFR in the events that were and were not included in the study. This might suggest that the wounding patterns are similar, but this cannot be ascertained without examination of all autopsies.

Given that we examined autopsy data only, there is a risk for selection bias in that we only examined those who died. Therefore, any treatment, such as tourniquet-based hemorrhage control, that was successful in saving lives would not have been documented in our study. We have attempted for 2 years to carry out a multicenter study to evaluate the characteristics of those who survived CMPS events, but this study requires a data use and IRB agreement with each individual hospital that cared for such patients. As of now, we still have not been able to amass a sufficient sample size to allow for any meaningful analysis. Current laws and lack of a national registry focused on firearm injury preclude the ability to carry out such a project in a timely fashion.

Determination of PPD is never a true objective end point, and we acknowledge this possible limitation. We attempted to minimize variability in conclusion by using a multidisciplinary panel of independent experts, which included the Chief Medical Examiner of Washington, DC; a panel of trauma surgeons, 2 of whom serve on the American College of Surgeons Committee on Trauma and have held national leadership positions in trauma surgery; an emergency medicine physician who is also the Operational Medical Director of an emergency medical services agency; and a critical care paramedic with nationally recognized expertise in mass casualty events. This process was more stringent than that used by the American College of Surgeons in verifying quality of care rendered by trauma centers in the US and followed the same process used by the US Department of Defense to determine causes of deaths in combat.[26,27]

Lastly, we would stress that because the study included only victims of CPMS, the conclusions do not apply to non-CPMS events, such as bombings or vehicle rammings. The mechanisms of injury between CPMS and non-CPMS mass casualty events differ significantly, and the latter events require separate study based on a different data set.

CONCLUSIONS

This study found that the vast majority of persons involved in CPMS events will die at the scene. In the wake of a CPMS event, treatment paradigms to mitigate the risk of PPD must start soon after the moment of wounding, must address all common causes of death, and must stress the need for coordinated rescue and rapid extrication of victims to advanced medical care.

Author Contributions

Study conception and design: Smith, Sarani, Shapiro
Acquisition of data: Smith, Sarani, Shapiro, Gondek, Robinson, Estroff, Fudenberg, Mitchell
Analysis and interpretation of data: Smith, Sarani, Shapiro, Gondek, Robinson, Estroff, Amdur, Mitchell
Drafting of manuscript: Smith, Sarani, Shapiro, Gondek, Rivas, Ju, Robinson, Estroff, Fudenberg, Amdur, Mitchell
Critical revision: Smith, Sarani, Shapiro, Rivas, Ju, Robinson, Estroff

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