Clustered Arrivals of Firearm-Injured Patients in an Urban Trauma System: A Silent Epidemic

Jessica H Beard, MD, MPH, Shelby Resnick, MD, MSEd, Zoë Maher, MD, FACS, Mark J Seamon, MD, FACS, Christopher N Morrison, PhD, Carrie A Sims, MD, PhD, FACS, Randi N Smith, MD, MPH, Lars O Sjoholm, MD, FACS, Amy J Goldberg, MD, FACS

BACKGROUND: Recent attention has been paid to the role trauma centers play in responding to mass shootings. Although high-profile public events are the primary focus of media and policy makers, firearm-injured patients (FIPs) present in clusters to urban trauma centers every day. We examined the burden of FIP clusters from an urban trauma system perspective.

STUDY DESIGN: In this descriptive epidemiologic study, we used data from the Philadelphia Police Department registry of shootings from 2005 to 2015. Variables included patient demographics, injury date and time, receiving hospital, and mortality. We defined clustered FIPs as those arriving within 15 minutes of another FIP. We used rolling temporal windows to calculate the number of FIP clusters for each hospital, assessed patient demographic characteristics and mortality, and used linear regression models to evaluate trends in FIP cluster rates.

RESULTS: Of the 14,217 FIPs included, 22.1% were clustered. There were 54 events when 4 or more FIPs presented within 15 minutes and 92 events when 4 or more FIPs presented within 60 minutes. Clusters of FIP occurred most frequently during night shifts (7:00 PM to 7:00 AM) (73.1%) at level I trauma centers (93.6%), with geographic clustering demonstrated at the hospital level. Compared with the overall FIP population, clustered FIPs were more likely to be female ($p = 0.039$), injured at night ($p = 0.031$), but less likely to die ($p = 0.014$). The rate of FIP clusters and mortality remained steady over the course of the study.

CONCLUSIONS: In the trauma system studied, FIP clusters are common and are likely to occur at similar rates in other urban centers. Therefore, the immediate burden on health care resources caused by multiple FIPs presenting within a short period of time is not limited to traditionally defined mass shootings. (J Am Coll Surg 2019;229:236–243. © 2019 by the American College of Surgeons. Published by Elsevier Inc. All rights reserved.)

Disclosure Information: Nothing to disclose.

Presented at the Eastern Association for the Surgery of Trauma 32nd Annual Scientific Assembly, Austin, TX, January 2019.

Received February 18, 2019; Revised March 28, 2019; Accepted March 28, 2019.

From the Departments of Surgery, Division of Trauma Surgery and Surgical Critical Care, Lewis Katz School of Medicine, Temple University (Beard, Maher, Sjoholm, Goldberg) and the Division of Traumatology, Surgical Critical Care, and Emergency Surgery, Perelman School of Medicine, University of Pennsylvania (Seamon, Sims), Philadelphia, PA, and the Division of Trauma/Surgical Critical Care at Grady Memorial Hospital, Emory University School of Medicine, Atlanta, GA (Smith); Kaiser Permanente South Sacramento Medical Center, Sacramento, CA (Resnick); the Department of Epidemiology and Preventive Medicine, Monash University, Melbourne, Australia (Morrison); and the Department of Epidemiology, Mailman School of Public Health, Columbia University, New York, NY (Morrison).

Correspondence address: Jessica H Beard, MD, MPH, Lewis Katz School of Medicine, Temple University, 3401 N Broad St, 4th Floor, Zone C, Philadelphia, PA 19140. email: jbeard08@gmail.com

The trauma system in the US was developed to provide organized care for acutely injured patients within a defined geography. By definition, a mass casualty incident (MCI) is an event in which the number of injured patients overwhelms the resources of the local trauma center and/or regional trauma system. In response to an increasing number of MCIs from mass shootings in the US, the American College of Surgeons issued the Hartford Consensus and its iterations, which contain recommendations for management of active shooter events and MCIs to improve survival.[1] In addition, the Stop the Bleed campaign was developed to instruct both the lay public and health care providers in pre-hospital hemorrhage control techniques.[2]

Although disaster preparedness is a vital component of any trauma system, traditionally defined mass

https://doi.org/10.1016/j.jamcollsurg.2019.03.020
ISSN 1072-7515/19

Abbreviations and Acronyms
FIP = firearm-injured patient
MCI = mass casualty incident
PPD = Philadelphia Police Department
PTSF = Pennsylvania Trauma Systems Foundation

shootings involving 3, 4, or more people killed in a single incident make up a tiny fraction of gun deaths in the US.[3] In turn, large scale MCIs from firearm violence remain relatively rare. More commonly, firearm-injured patients (FIPs) present to trauma centers as a single victim or in clusters of multiple casualties, which do not achieve the definition of mass shooting or MCI. Research by Livingston and colleagues[4] has suggested that the rate of clustered hospital arrivals of FIPs may be increasing over time in Newark, NJ. However, the implications for trauma system resources and effects of clustering on patient outcomes are unclear. Although it is commonly believed that patients involved in MCIs have worse outcomes, an analysis from a level I trauma center in Baltimore, MD found that clustering did not affect outcomes for seriously injured patients presenting with blunt and/or penetrating mechanisms.[5,6]

From a trauma system perspective, it is important to document and monitor the frequency and magnitude of clustered arrivals of FIPs. With a better understanding of the burden FIP clusters have on our hospitals and trauma systems, improved resource allocation and management plans for multiple patient scenarios can be developed to avoid MCIs. Although rates of clustered trauma patients have been documented at the individual hospital level, there has been no study that has examined the rate at which firearm-injured patients present in clusters in an urban trauma system.[4,5]

The purpose of this study was to calculate the number and analyze trends in the rates of FIPs transported at clustered time intervals to Philadelphia area hospitals over an 11-year period. In addition, we examined FIP demographics and mortality, time of day of FIP transport, and level of treating trauma center over the same study period, comparing these characteristics between FIP clusters and the overall FIP population. Based on the Livingston study, we hypothesized that FIP clusters would be common, increasing over time, and more likely to present at level I trauma centers when compared with other levels of trauma centers or non-trauma centers.[4]

METHODS

Data source

In the US, there is no national data source that includes fatal and nonfatal firearm injuries available for analysis at the city level. In the state of Pennsylvania, the Pennsylvania Trauma Systems Foundation (PTSF) collects comprehensive data on injured patients for surveillance in its statewide registry. However, many firearm-injured patients do not meet PTSF criteria for registry inclusion, so the state trauma registry remains limited for use in investigations of local firearm injury epidemiology.

For this study, we elected to use data from the Philadelphia Police Department (PPD), the most comprehensive source of city-level firearm injury data available in Philadelphia. The PPD collects data on all "criminal shootings" in which a victim is shot or killed. All shooting victims are included in the dataset regardless of mode of transport to the hospital. The PPD shooting data do not include self-inflicted gunshot wounds. This dataset has been used in previous research by our team examining the epidemiology of firearm violence in Philadelphia, and a subset of the data is publicly available.[7-10] The PPD dataset includes the following variables: victim demographic characteristics (age, race, sex), block level location of shooting event, date and time firearm injury was called into PPD, mortality, and receiving hospital. Because police provide transport for a significant number of FIPs to hospitals in Philadelphia, the reliability of this dataset is likely very high.[11]

Data collection, analysis, and ethics

Using the PPD dataset, all FIPs transported to a Philadelphia area hospital from January 1, 2005 to December 31, 2015 were included in the study. Firearm-injured patients with missing data on shooting time and/or hospital destination were excluded. Based on previous work by Livingston and colleagues,[4] we defined an FIP cluster as the arrival of more than 1 firearm-injured patient within 15 minutes of another. We also evaluated patients arriving within 60 minutes of each other. We used rolling temporal windows to calculate the number of FIP clusters involving 2 or more patients within the specified time intervals for each hospital. This method ensured that shootings that were proximal in time would not be arbitrarily separated. In our analysis, we evaluated time continuously rather than separating 15-minute intervals based on the time of day or on the time elapsed after an index case.

As an example, 3 events occurred at 7:01, 7:08, and 7:17. Fixed 15-minute intervals (eg from 7:00 AM to 7:15 AM) and fixed time windows after the index event would identify this group as a cluster of 2 events and a single event. With rolling temporal windows, the time window begins again with each case, so this group would be considered 1 cluster of 3 events. "Rolling temporal windows" is not a biostatistical definition, but we considered it to be the approach that was most consistent with the phenomenon of interest. We assumed that the recorded call time to PPD recorded in the dataset would be similar to hospital arrival time given short pre-hospital police transport times in Philadelphia.

Each hospital was assigned a letter for ease of analysis and to protect center anonymity. We used descriptive statistics to analyze patient demographics and mortality, comparing FIPs who presented in clusters to the overall FIP population. Continuous variables were compared using Student's *t*-test, while dichotomous variables were compared using chi-square tests, as appropriate. Values are reported as mean ± standard deviation (SD) for continuous variables and as percentages for categorical variables. Trends in rates of FIP presentation by hospital level, mortality, and FIP clusters over time were evaluated using linear regression. A value of $p < 0.05$ was considered statistically significant. We used IBM SPSS Version 24.0 (IBM Corp) and Stata Version 14.0 (StataCorp) for data analysis. The University of Pennsylvania Institutional Review Board approved this study.

RESULTS

Over the 11-year study period, there were 15,392 FIPs in the complete PPD dataset; 1,175 FIPs (7.6%) were excluded because of missing data. Of the excluded FIPs, 11 had missing data for date and/or time, and 1,164 were missing the hospital destination. The remaining 14,217 included in the study FIPs were treated at 18 hospitals in the Philadelphia area. The majority of FIPs were male (n = 13,109, 92.2%), young (mean age 27.1 ± 10.2 years), and black (n = 11,979, 84.3%). There were 1,978 fatalities (13.9%), and the mortality rate did not change over the study period (14.3% in 2005 to 15.0% in 2015; change/year 0.01, 95% CI -0.28, 0.31; p = 0.925). Most FIPs arrived during the night shift (7:00 PM to 7:00 AM) (n = 10,115, 71%), and the rate of night shift arrivals was similar across all hospital types (level I centers: n = 9,140, 71.2%; level II centers: n = 259, 72.1%; nontrauma centers: n = 716, 70.1%).

Of the hospitals studied, 7 were level I trauma centers (hospitals A to G), 3 were level II trauma centers (hospitals H to J), and 8 were not trauma centers (hospitals K to R). The majority of patients were treated at level I trauma centers (n = 12,837, 90.3%), followed by nontrauma centers (n = 1,021, 7.2%), and then by level II centers (n = 359, 2.5%). There was no change in the proportion of FIPs treated at level I trauma centers over the study period (90.4% in 2005 to 92.1% in 2015; change/year: -0.21; 95% CI -0.04, 0.50; p = 0.085). In contrast, the proportion of patients treated at level II centers increased (0.13% in 2005 to 4% in 2015; change/year: 0.61; 95% CI 0.33, 0.90; $p < 0.001$), while the proportion treated at nontrauma centers decreased significantly during the study period (9.5% in 2005 to 3.9% in 2015; change/year: -0.84; 95% CI -1.20, -0.5; $p < 0.001$).

Analysis of firearm-injured patient clusters

As shown in Table 1, patient age and race were similar between FIPs arriving in clusters of 2 or more within 15 minutes and the overall FIP population. However, clustered FIPs were more likely to be female and present at night (p = 0.039 and 0.031, respectively). Firearm-injured patients presenting in clusters were less likely to die and less likely to present at level II or nontrauma centers than the general FIP population (p = 0.014, and $p < 0.001$, respectively).

Overall, 22.1% (n = 3,141) of FIPs arrived in 1,416 clusters of 2 or more patients (Table 2). Of these, 1,322 clusters (93.4%) were cared for at level I trauma centers, 27 clusters (1.9%) at level II, and 67 clusters (4.7%) at nontrauma centers. Twenty-three percent (n = 2,939) of all FIPs arrived within 15 minutes of another FIP at level I trauma centers. The proportions of FIP clusters treated at level II and nontrauma centers were lower than level I rates, but were similar to each other, at 15.9% (n = 57 clusters) and 14.2% (n = 145 clusters), respectively.

The majority of cluster events occurred when 2 FIPs arrived within 15 minutes of each other (n = 1,172 clusters, 82.7%). Seven hundred ninety-seven (5.6%) FIPs arrived in 244 clusters of 3 or more, and 227 FIPs arrived in 54 clusters of 4 or more (1.6%). There was a trend toward increase in the percentage of FIPs arriving in clusters of 2 or more within 15 minutes (change/year: 0.41; 95% CI -0.0007, 0.83; p = 0.050) (Fig. 1). Firearm-injured patients arriving in 15-minute clusters had a lower mortality rate when compared with the overall FIP population (12.2% vs 13.9%, p = 0.014).

Sixty-minute clusters

Overall, 28.3% (4,023) of FIPs arrived in 1,770 clusters of 2 or more within 60 minutes (Table 3). Of these, 1,669 clusters (94.3%) were at level I trauma centers, 29 clusters (1.6%) were at level II, and 72 clusters

Table 1. Comparison of Clustered Firearm-Injured Patients vs All Firearm-Injured Patients

Variable	≥2 FIPs in 15 min (n = 3,141)	FIPs (n = 14,217)	p Value
Age, y, mean ± SD	27.3 ± 10.4	27.1 ± 10.2	0.518
Male sex, n (%)	2,861 (91.1)	13,109 (92.2)	0.039
Race, n (%)			
Black	2,670 (85.0)	11,979 (84.3)	
White	435 (13.8)	2,083 (14.7)	0.310
Fatal, n (%)	384 (12.2)	1,978 (13.9)	0.014
Night shift, n (%)	2,297 (73.1)	10,115 (71.1)	0.031
Hospital, n (%)			
Level I center	2,939 (93.6)	12,837 (90.3)	<0.001
Level II center	57 (1.8)	359 (2.5)	0.022
Nontrauma center	145 (4.6)	1,021 (7.2)	<0.001

FIPs, firearm-injured patients.

(4.1%) were at nontrauma centers. Twenty-nine percent (n = 3,800) of FIPs arrived clustered at level I trauma centers. The proportions of FIP clusters treated at level II and nontrauma centers were lower than level I rates, but were similar to each other, at 17% (61 clusters) and 15.6% (159 clusters), respectively.

The majority of clustered events occurred when 2 FIPs arrived within 60 minutes of each other (n = 1,403, 79.2%). In total, 1,214 FIPs arrived in clusters of 3 or more (8.6%), and 392 FIPs arrived in clusters of 4 or more (2.8%). Over time, the percentage of FIPs arriving in clusters of 2 or more within 60 minutes remained steady (change/year: 0.29; 95% CI -0.10, 0.68; p = 0.142) (Fig. 1). Firearm-injured patients arriving in 60-minute clusters had a lower mortality rate when compared with the overall FIP population; however, the difference was not significant (12.8% vs 13.9%, p = 0.074).

High-volume clusters

Over the study period, there were 3 events at which 6 or more FIPs arrived at a single hospital within 15 minutes. These events are further analyzed in Table 4. The highest number of FIPs arriving in a single cluster was 7, which occurred between 8:45 PM and 9:00 PM in 2010. In addition to this single event of 7 FIPs, there were 2 events

Table 2. Characteristics of 15-Minute Firearm-Injured Patient Clusters

	FIPs in clusters, n							Total FIPs in clusters, %		
Characteristic	2 (n = 1,172)	3 (n = 190)	4 (n = 47)	5 (n = 4)	6 (n = 2)	7 (n = 1)	Total (n = 1,416)	≥2	≥3	≥4
Year										
2005	128	24	1	0	0	0	153	21.8	5.0	0.3
2006	125	19	3	2	0	0	149	19.2	4.6	1.3
2007	102	13	6	0	0	0	121	18.5	4.4	1.7
2008	96	18	3	0	0	0	117	20.0	5.1	0.9
2009	110	17	5	1	0	0	133	23.4	6.0	2.0
2010	118	20	8	0	1	0	147	24.3	7.1	2.8
2011	127	15	5	1	0	1	149	25.3	5.9	2.4
2012	101	14	7	0	0	0	122	23.2	6.0	2.4
2013	84	19	3	0	0	0	106	23.1	6.7	1.2
2014	80	12	2	0	0	0	94	21.4	4.6	0.8
2015	101	19	4	0	1	0	125	24.7	6.9	1.9
Hospital										
Level I (7 centers)	1,090	180	45	4	2	1	1,322	22.9	5.9	1.7
Level II (3 centers)	25	1	1	0	0	0	27	15.9	1.9	1.1
Nontrauma (8 hospitals)	57	9	1	0	0	0	67	14.2	3.0	0.4

FIPs, firearm-injured patients.

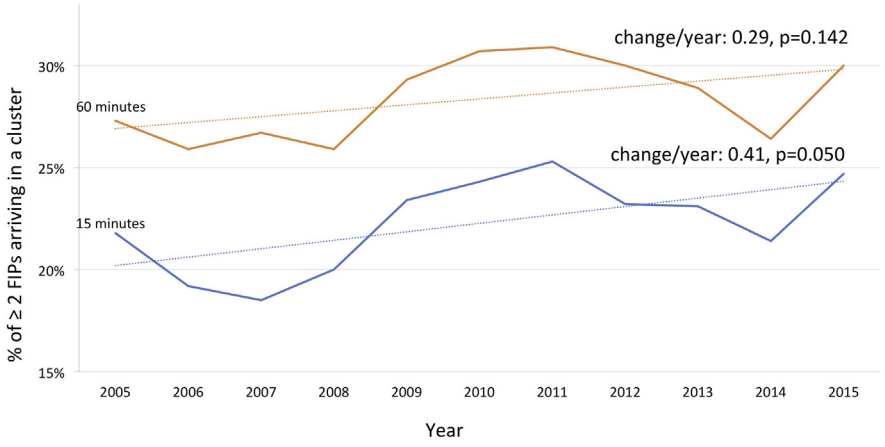

Figure 1. Trends in firearm-injured patient (FIP) clusters by time intervals, 2005 to 2015.

at which 6 FIPs presented within 15 minutes. All occurred during night shifts at Hospital D, a level I trauma center. Of the 19 FIPs involved in the high volume clusters, 1 died (5.3%) and 8 were women (42.1%).

Firearm-injured patient clusters by geography

In addition to temporal clustering, FIPs were geographically clustered. Of the 18 hospitals included in the study, 3 Philadelphia level I trauma centers (A, D, G) treated 77.8% (n = 11,061) of the entire FIP population. These same 3 centers saw the highest number of clustered FIPs as well, treating 83.3% (n = 1,180) of clusters of 2 or more FIPs arriving within 15 minutes and 85.2% (n = 46) of 4 or more FIP clusters. For 2 or more FIPs arriving in the 60-minute clusters, 3,456 (86.0%) were brought to these 3 centers. Similarly, they treated 91.8% (n = 358) of FIPs arriving in 60-minute clusters of 4 or more FIPs (Fig. 2). Of note, all high volume clusters (6 or more FIPs in the cluster) were treated at a single level I trauma center, Hospital D.

DISCUSSION

This study demonstrates that a significant proportion of FIPs present in clusters in the urban trauma system studied. During the study period, nearly 1 in 4 FIPs presented

Table 3. Characteristics of 60-Minute Firearm-Injured Patient Clusters

	FIPs in clusters, n							Total FIPs in clusters, %		
Characteristic	2 (n = 1,404)	3 (n = 274)	4 (n = 74)	5 (n = 15)	6 (n = 2)	7 (n = 1)	Total (n = 1,770)	≥2	≥3	≥4
Year										
2005	149	32	3	2	0	0	186	27.3	7.8	1.4
2006	160	26	5	5	0	0	196	25.9	7.2	2.6
2007	135	24	10	1	0	0	170	26.7	8.1	3.1
2008	117	24	6	1	0	0	148	25.9	7.8	2.2
2009	122	28	8	2	0	0	160	29.3	10.0	3.3
2010	135	30	13	1	1	0	180	30.7	11.1	4.6
2011	140	25	8	2	0	1	176	30.9	9.5	3.7
2012	129	18	10	0	0	0	157	30.0	8.0	3.4
2013	104	23	5	0	0	0	132	28.9	8.7	1.9
2014	96	16	3	0	0	0	115	26.4	6.3	1.3
2015	117	28	3	1	1	0	150	30.0	9.4	2.0
Hospital										
Level I (7 centers)	1,319	260	72	15	2	1	1,669	29.6	9.1	3.0
Level II (3 centers)	27	1	1	0	0	0	29	17.0	1.9	1.1
Nontrauma (8 hospitals)	58	13	1	0	0	0	72	15.6	4.2	0.4

FIPs, firearm-injured patients.

Table 4. Characteristics of 15-Minute Clusters of 6 or More Firearm-Injured Patients

Year	No. of FIPs in cluster	Time of arrival	Age range, y	Fatality count, n	Sex	Hospital
2010	6	2:28 AM	17–26	0	5 male, 1 female	D
2015	6	9:40 PM to 9:50 PM	16–33	1	3 male, 3 female	D
2011	7	8:45 PM to 9:00 PM	15–35	0	7 male	D

Hospital D is a level I trauma center.
FIPs, firearm-injured patients.

within 15 minutes of another FIP. There were 54 events when 4 or more FIPs presented within 15 minutes. Over an 11-year period, this amounts to a mass shooting-type event (involving 4 or more victims) occurring every 2 to 3 months in the Philadelphia area alone. For comparison, there were just 43 mass shootings recorded by media source Mother Jones and 165 "active shooter incidents" according to the Federal Bureau of Investigation (FBI) over the same time period in the entire US.[12,13] In fact, there have been no mass shootings in the city of Philadelphia since 1982, according to Mother Jones.[13] Therefore, FIP clusters, which can cause trauma system stress with still unclear effects on patient outcomes, are not widely recognized within the traditional framework of "mass shootings" by media or policy makers. However, for hospitals that treat the injured, it is likely that the number of FIPs, the time between arrivals, and the injury severity that determine the level of system burden, regardless of whether the event in which they occurred was a single event that meets the traditional definition of "mass shooting."

The majority of FIP clusters were treated at level I trauma centers during the study period. However, there were 27 and 67 FIP clusters (2 or more FIPs in 15 minutes) brought to level II trauma centers and nontrauma centers, respectively. There were 2 events when 4 or more FIPs presented within 15 minutes at non-level I trauma centers. Although FIP clusters likely place strain on any level of trauma center, smaller hospitals with fewer resources may be less equipped to care for these high volumes of patients. In these smaller hospitals, it is therefore more likely that a higher volume FIP cluster could result in a mass casualty incident. In addition, many FIPs initially treated at nontrauma centers may

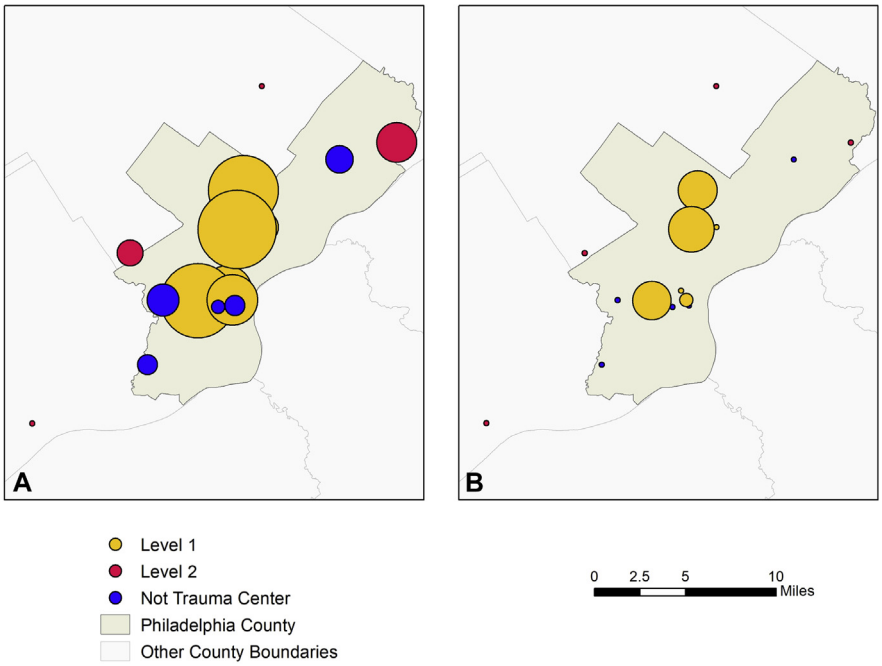

Figure 2. Geographic distribution of firearm-injured patient (FIP) clusters in Philadelphia, 2005 to 2015, (A) Two or more FIPs within 15 minutes and (B) 4 or more FIPs within 60 minutes. Each circle represents a single hospital color-coded by trauma center level. The size of the circle corresponds to the volume of FIP clusters treated at each hospital, and the center of the circle is the geographic point location of the hospital.

require transfer to a higher level of care, a burden that is not captured in this study and could potentially result in system strain and drainage of resources.

The mortality rate of FIPs treated at level I trauma centers was higher when compared with level II centers and nontrauma centers. One possible explanation for this finding is that the most critically injured patients are being triaged appropriately to the highest level of care. Although it was not possible to control for injury severity with the PPD data, an analysis using injury severity would serve to clarify the relationship between trauma center level and mortality in future studies.

Interestingly, the injuries sustained by clustered FIPs were less likely to be fatal than those in the general population of FIPs. The overall mortality rate seen in this study (13.9%) is similar to that reported in Newark, NJ (9% to 14%) and slightly lower than the in-hospital case-fatality rate for gunshot wound patients in Denver (22.9%).[4,14] Of note, the mortality rate in this study is notably much lower than that reported by Smith and associates[15] in their analysis of autopsies of civilian public mass shootings (44%). The mass shootings in that study all involved more than 6 victims (maximum number of victims was 70), and many involved high-velocity weapons, which are less commonly seen in urban firearm injury. It is possible that FIP clusters in this study may be less severely injured than victims of active shooters or the general FIP population in Philadelphia, because they may be bystanders or unintended targets of the shooter. Related to this, we found that women were more disproportionately injured within FIP clusters. Although our data cannot explain this finding, it is possible that some high casualty incidents involve domestic violence or that women are more likely to be unintended targets than men. More research is needed to understand this gender disparity within FIP clusters.

Over the study period, transport of FIPs to level II centers increased, while transport to nontrauma centers decreased. This is an interesting finding that demonstrates the evolution of the Philadelphia-area trauma system over time. During the study period, several nontrauma centers that had received patients closed, potentially explaining these results.

In Philadelphia, the police are responsible for a significant portion of pre-hospital transport of patients with penetrating trauma.[11] Data suggest that this "scoop and run" policy practiced by Philadelphia police is associated with similar, and possibly even improved, outcomes after penetrating injury when compared with traditional pre-hospital care provided by emergency medical services.[11,16-19] However, there may be room for improvement in the logistics of police transport in Philadelphia. Although PPD policy dictates notification of police radio of "injury type and hospital designation," the police do not have a standard protocol for communicating with the receiving hospital.[20] In addition, although police officers are instructed to transport patients to the nearest trauma center, there is no explicit policy concerning triage in multiple victim scenarios.[20] In the case of multiple injured victims, more coordination between the transporting police officers and receiving hospital could optimize triage, ensuring that the volume and acuity of FIPs transported to each hospital matches available resources.

Urban firearm violence is thought to occur in geographic "hot spots."[21,22] In this study, we have shown that care for multiple victim shootings clusters around a few hospitals in Philadelphia. Much like a city block could be identified as a location for violence intervention, hospitals that care for high volumes of clustered FIPs have unique staffing and resource needs. Understanding how these hospitals manage multiple critically injured patients now, as well as identifying areas for improvement, is key going forward as patterns and locations of gun violence can change over time.

This study has limitations inherent in the data source and design. First, the assumption that police notification time and hospital arrival time are similar introduces bias that cannot be measured. In addition, the dataset does not include trauma patients injured by other mechanisms, who may have been evaluated and cared for at the same time as the FIPs. This most likely results in underestimate of system stress from FIP clusters. Although we did base our definitions of FIP clustering on previous literature, there is no standard definition for what constitutes an FIP cluster. Within a 15-minute cluster, FIPs would likely be simultaneously evaluated in the trauma bay. Within a 60-minute cluster, resources in the blood bank, operating room, CT scanner, staff, and trauma bay could be strained without time to recover from treatment of the preceding patient. We propose that these 2 time frames be used in future studies examining clusters of FIPs going forward. Finally, the study is descriptive in nature and the true effect of clustering of FIPs on outcomes, including mortality, cannot be assessed with the current data source. It is possible that the observed mortality difference between clustered FIPs and the general FIP population was statistically, but not clinically, significant due to the large sample size.

CONCLUSIONS

In Philadelphia, clusters of firearm-injured patients are common and are likely to occur at similar rates in other urban centers. Although the FBI recorded no active shooter events in Philadelphia over the study period, there

were 54 mass-shooting type events involving 4 or more patients presenting to a single hospital. Therefore, the immediate burden on health care resources caused by multiple FIPs presenting within a short period of time is not limited to traditionally defined mass shootings. Our findings highlight that a significant portion of firearm injury disease burden, even for high casualty incidents, lies in urban centers with high rates of neighborhood gun violence. Prevention efforts should be focused on these populations and places going forward.

The effects of patient clustering on outcomes after firearm injury are still unknown and are likely to differ across contexts. Timely transport to the nearest trauma center is necessary to optimize survival. Going forward, trauma centers should make an effort to collect data on FIP cluster rates and monitor outcomes on a local and national level.

Author Contributions

Study conception and design: Beard, Resnick, Seamon, Morrison, Sims, Smith, Goldberg
Acquisition of data: Beard
Analysis and interpretation of data: Beard, Resnick, Maher, Seamon, Morrison, Sims, Sjoholm, Goldberg
Drafting of manuscript: Beard, Resnick
Critical revision: Beard, Resnick, Maher, Seamon, Morrison, Sims, Smith, Sjoholm, Goldberg

REFERENCES

1. American College of Surgeons. The Hartford Consensus. Available at: https://www.facs.org/about-acs/hartford-consensus. Accessed December 19, 2018.
2. American College of Surgeons. Stop the Bleed. Available at: https://www.bleedingcontrol.org/. Accessed December 19, 2018.
3. Rand Corporation. Mass Shootings: Definitions and Trends. Available at: https://www.rand.org/research/gun-policy/analysis/supplementary/mass-shootings.html. Accessed February 18, 2019.
4. Livingston DH, Lavery RF, Lopreiato MC, et al. Unrelenting violence: an analysis of 6,322 gunshot wound patients at a Level I trauma center. J Trauma Acute Care Surg 2014;76:2–9; discussion 9–11.
5. Shoher A, Chang DC, Efrom D, et al. Multiple, simultaneous trauma patients: Are they worse off? J Trauma 2006;61:611–615.
6. Hirschberg A, Holcomb JB, Mattox KL. Hospital trauma care in multiple-casualty incidents: a critical view. Ann Emerg Med 2001;37:647–652.
7. Beard JH, Morrison CN, Jacoby SF, et al. Quantifying disparities in urban firearm violence by race and place in Philadelphia, Pennsylvania: A cartographic study. Am J Public Health 2017;107:371–373.
8. Jacoby SF, Dong B, Beard JH, et al. The enduring impact of historical and structural racism on urban violence in Philadelphia. Soc Sci Med 2018;199:87–95.
9. Jacoby SF, Kollar LMM, Ridgeway G, Sumner SA. Health system and law enforcement synergies for injury surveillance, control and prevention: a scoping review. Inj Prev 2018;24:305–311.
10. Open Data Philly. Shooting Victims. Available at: https://www.opendataphilly.org/dataset/shooting-victims. Accessed December 19, 2018.
11. Rappold JF, Hollenbach KA, Santora TA, et al. The evil of good is better: Making the case for basic life support transport for penetrating trauma victims in an urban environment. J Trauma Acute Care Surg 2015;79:343–348.
12. FBI Office of Partner Engagement. Quick Look: 250 Active Shooter Incidents in the US From 2000 to 2017. Available at: https://www.fbi.gov/about/partnerships/office-of-partner-engagement/active-shooter-incidents-graphics. Accessed July 6, 2018.
13. Follman M, Aronsen G, Pan D. US Mass Shootings, 1982-2018. Available at: https://www.motherjones.com/politics/2012/12/mass-shootings-mother-jones-full-data. Accessed July 6, 2018.
14. Sauaia A, Gonzalez E, Moore HB, et al. Fatality and severity of firearm injuries in a Denver trauma center, 2000-2013. JAMA 2016;315:2465–2467.
15. Smith ER, Shapiro G, Sarani B. The profile of wounding in civilian public mass shooting fatalities. J Trauma Acute Care Surg 2016;81:86–92.
16. Wandling MW, Nathens AB, Shapiro MB, Haut ER. Police transport versus ground EMS: A trauma system-level evaluation of prehospital care policies and their effect on clinical outcomes. J Trauma Acute Care Surg 2016;81:931–935.
17. Wandling MW, Nathens AB, Shapiro MB, Haut ER. Association of prehospital mode of transport with mortality in penetrating trauma: a trauma system-level assessment of private vehicle transportation vs ground emergency medical services. JAMA Surg 2018;153:107–113.
18. Bickell WH, Wall MJ Jr, Pepe PE, et al. Immediate versus delayed fluid resuscitation for hypotensive patients with penetrating torso injuries. N Engl J Med 1994;331:1105–1109.
19. Seamon MJ, Doane SM, Gaughan JP, et al. Prehospital interventions for penetrating trauma victims: a prospective comparison between Advanced Life Support and Basic Life Support. Injury 2013;44:634–638.
20. Philadelphia Police Department. Directive 3.14 for Hospital Cases. Effective date: March 8, 1996. Updated date: December 17, 2001.
21. Braga AA, Papachristos AV, Hureau DM. The concentration and stability of gun violence at micro places in Boston, 1980-2008. J Quant Criminol 2010;26:33–53.
22. Braga AA. The effects of hot spots policing on crime. Ann Am Acad Pol Soc Sci 2001;578:104–125.