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Gunshot Injuries in the Elderly: Patterns and Outcomes. A National Trauma Databank Analysis

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Abstract
Background Trauma in the elderly (≥55 years) accounts for a significant proportion of admissions to trauma centers. Our understanding of the epidemiology and outcomes associated with penetrating injury in this age segment of the population, however, is severely limited. The aim of the present study therefore was to investigate the incidence and type of injuries sustained by elderly patients from firearms and the impact of age on outcomes.
Methods This was a 5-year National Trauma Databank (NTDB) study. Injury demographics, mortality rates, and lengths of stay in the Intensive Care Unit (ICU) and the hospital were analyzed. Elderly patients ≥55 years old were assigned to one of three categorical strata: 55–64 years old, 65–74 years old, and ≥75 years old.
Results During the study period, 98,242 patients were admitted for firearm-related injuries, and 3,190 (3.2%) of them were ≥55 years old. Within the elderly age segment of the population, 1,676 patients (52.5%) were 55–64 years of age, 727 (22.8%) were 65–74 years of age, and 787 (24.7%) were ≥75 years old. The incidence of severe trauma [Injury Severity Score (ISS) ≥ 16] in the elderly age strata was 43.3, 46.8, and 57.6%, respectively ($p < 0.001$). Patients ≥75 years old were significantly more likely than patients 55–74 years old to suffer self-inflicted injuries. The most commonly encountered injury in elderly patients was gunshot wounds to the head, which increased in a stepwise fashion with advancing age (25.8, 31.6, and 39.4% respectively; $p < 0.001$). The crude mortality rate in all patients sustaining gunshot wounds increased progressively with age. Within the elderly age segment, mortality ranged from 28.5% in the age stratum 55–64 years, to 55.4% in the stratum ≥75 years (adjusted $p < 0.001$). Intensive care unit and hospital length of stay increased with advancing age but peaked and remained stable among the elderly age groups. An admission Glasgow Coma Score (GCS) ≤ 8, an ISS ≥ 16, hypotension on admission, age, self-inflicted injury, and injury sustained by assault were factors independently associated with death in patients ≥55 years.
Conclusions Injury from firearms is not uncommon in the elderly patient population and is primarily a result of self-inflicted gunshot wounds to the head. These patients sustain a high burden of injury and a high rate of mortality, which increases with advancing age.

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Introduction

The geriatric population is the fastest growing age group today [1], and trauma to this age segment of the population accounts for a significant proportion of admissions to trauma centers. Classically, injuries sustained by elderly patients were thought to be blunt, consisting primarily of falls, motor vehicle collisions, and pedestrian events. However, penetrating injuries, particularly involving firearms, were recently reported by the Centers for Diseases Control and Prevention to account for over 50% of assault-related fatal injuries in the elderly [2]. Very few studies exist examining the impact of penetrating injuries on the geriatric population [3, 4]. Contemporary, nationwide epidemiologic data on firearm-related injuries in elderly

trauma patients is likewise scarce in the medical literature. Consequently, our understanding of the problem is very limited.

We hypothesized that gunshot injuries represent a significant healthcare problem among elderly trauma patients and that those patients have poorer outcomes than their younger counterparts. Thus, the purpose of the present study was to evaluate incidence of and outcomes after gunshot injury in the elderly age segment, to relate these outcomes to those in younger trauma patients, and to identify risk factors for death in the geriatric trauma population.

Patients and method

The National Trauma Databank (NTDB) version 7.0, which includes nationwide data on trauma patients from 2002 to 2006, was used for the purposes of this study. All patients sustaining gunshot wounds were identified by the code for the external cause of injury (E-code) of the International Classification of Diseases—9th Revision (E922.0-.3, .8, .9; E955.0-.4; E965.0-.4; E985.0-.4; E970.0). The following data were abstracted and analyzed: age, gender, intent of injury (assault, self-inflicted, unintentional), Injury Severity Score (ISS), systolic blood pressure (SBP), and Glasgow Coma Scale (GCS) on admission. Continuous variables were subsequently dichotomized using clinically relevant cut-points: GCS on admission ($\leq$8 versus >8), SBP on admission ($\leq$90 mmHg versus >90 mmHg), and ISS ($\geq$16 versus <16 and $\geq$25 versus <25). All injuries sustained were also abstracted. Outcomes included mortality, hospital and ICU length of stay (LOS), and discharge disposition.

For the analysis, we assigned patients $\geq$55 years old to one of three categorical strata: 55–64 years old, 65–74 years old, and $\geq$75 years old. Comparison with regard to the anatomic distribution of the injuries (head, chest, abdomen, extremity) within the elderly trauma population was performed. The chi-square test or Fisher's exact test was used for the comparison of categorical variables; analysis of variance was used for the comparison of continuous variables. To obtain adjusted differences in outcomes for the elderly population, logistic regression was performed to control for factors that were significantly different ($p < 0.05$) between compared groups. For continuous outcomes, analysis of covariance was used to adjust for confounders that were significant at $p < 0.05$. Additionally, crude outcome variables of the elderly age segment were compared to those in younger trauma patients.

To identify risk factors for mortality in elderly trauma patients, a stepwise forward logistic regression analysis was performed. Risk factors with a p value <0.2 from the bivariate analysis were included in the model.

Values are reported as mean ± standard error of the mean (SEM) for continuous variables and as percentages for categorical variables. All analyses were performed using the Statistical Package for Social Sciences (SPSS Windows), version 12.0 (SPSS Inc., Chicago, IL).

Results

During the 5-year study period, 98,242 patients who sustained a gunshot injury were identified in the NTDB. Figure 1 demonstrates the incidence of firearm-related injuries within the different age groups. A peak was observed in the age segment 15–24 years (10.8%), gradually decreasing thereafter, with the lowest incidence (0.5%) found in patients $\geq$75 years.

A total of 3,190 patients admitted for gunshot injuries were aged $\geq$55 years. This accounted for 0.7% of all patients $\geq$55 years, and for 3.2% of all patients sustaining gunshot wounds. There were 1,676 patients (52.5%) in the age stratum 55–64 years, 727 (22.8%) in the age stratum 65–74 years, and 787 (24.7%) in the age stratum $\geq$75 years. Table 1 summarizes demographic and admission characteristics of the three elderly age groups. Overall, 481 elderly patients (15.5%) sustained severe (ISS $\geq$ 16, <25) injuries, and 1,000 patients (32.2%) presented with critical injuries (ISS $\geq$ 25). Severe and critical injuries increased significantly with advancing age within the elderly age segment. While the occurrence of assault decreased significantly with advancing age (48.0 versus 31.9 versus 28.6%; $p < 0.001$), self-inflicted gunshot injuries in suicide attempts increased significantly (29.2 versus 46.2 versus 56.4%; $p < 0.001$) (Table 1).

Table 2 delineates specific injuries sustained by the elderly patients as a result of the gunshot. The most common injury type was head trauma ($n = 972$; 30.5%), followed by chest ($n = 545$; 17.1%) and abdominal trauma

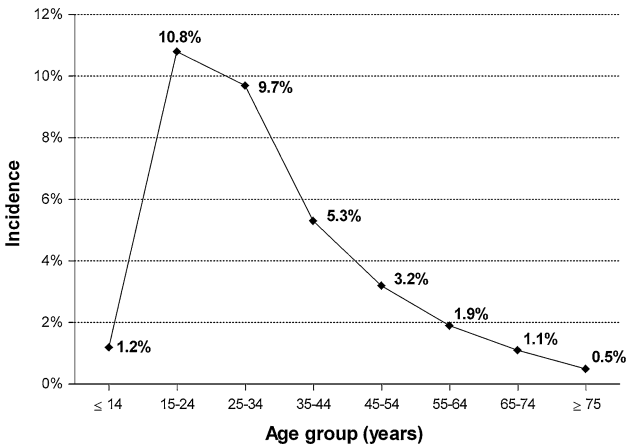

Fig. 1 Incidence of firearm-related injuries stratified by age groups

Table 1 Demographic and admission characteristics among elderly trauma patients with gunshot wounds stratified by age

	Total ($n = 3,190$)	55–64 years ($n = 1,676$)	65–74 years ($n = 727$)	≥75 years ($n = 787$)	p Value
Male	86.4% (2,753/3,186)	86.4% (1,448/1,675)	85.0% (617/726)	87.6% (688/785)	0.321
GCS ≤ 8	38.8% (1,126/2,901)	32.3% (492/1,524)	38.7% (255/659)	52.8% (379/718)	<0.001
SBP < 90 mmHg	21.6% (652/3,017)	19.3% (306/1,588)	20.1% (137/681)	27.9% (209/748)	<0.001
ISS, mean ± SEM	15.9 ± 0.2	15.0 ± 0.3	15.5 ± 0.5	18.1 ± 0.5	<0.001
ISS ≥ 16	47.6% (1,481/3,109)	43.3% (704/1,627)	46.8% (332/710)	57.6% (445/772)	<0.001
ISS ≥ 25	32.2% (1,000/3,109)	28.4% (462/1,627)	32.8% (233/710)	39.5% (305/772)	<0.001
Intent of injury					
Unintentional	14.5% (462/3,190)	16.0% (268/1,676)	16.1% (117/727)	9.8% (77/787)	<0.001
Assault	39.5% (1,261/3,190)	48.0% (804/1,676)	31.9% (232/727)	28.6% (225/787)	<0.001
Self-inflicted	39.8% (1,269/3,190)	29.2% (489/1,676)	46.2% (336/727)	56.4% (444/787)	<0.001

GCS Glasgow Coma Scale; *SBP* systolic blood pressure; *ISS* injury severity score; *SEM* standard error of the mean

Table 2 Overall specific injuries among elderly trauma patients with gunshot wounds stratified by age

	Total, % ($n = 3,190$)	55–64 years, % ($n = 1,676$)	65–74 years, % ($n = 727$)	≥75 years, % ($n = 787$)	p Value
Head trauma	30.5 (972/3,190)	25.8 (432/1,676)	31.6 (230/727)	39.4 (310/787)	<0.001
Chest trauma	17.1 (545/3,190)	17.4 (292/1,676)	14.6 (106/727)	18.7 (147/787)	0.092
Abdominal trauma	14.2 (454/3,190)	16.3 (273/1,676)	12.7 (92/727)	11.3 (89/787)	0.002
Extremity fracture	13.4 (426/3,190)	16.3 (273/1,676)	12.2 (89/727)	8.1 (64/787)	<0.001

Table 3 Self-inflicted injuries among elderly trauma patients with gunshot wounds stratified by age

	Total, % ($n = 1,269$)	55–64 years, % ($n = 489$)	65–74 years, % ($n = 336$)	≥75 years, % ($n = 444$)	p Value
Head trauma	54.5 (691/1,269)	54.8 (268/489)	52.7 (177/336)	55.4 (246/444)	0.736
Chest trauma	14.8 (188/1,269)	17.0 (83/489)	12.8 (43/336)	14.0 (62/444)	0.208
Abdominal trauma	8.7 (111/1,269)	9.2 (45/489)	8.3 (28/336)	8.6 (38/444)	0.896
Extremity fracture	2.4 (30/1,269)	3.7 (18/489)	1.2 (4/336)	1.8 (8/444)	0.043

($n = 454$; 14.2%). The incidence of head injuries increased progressively with age. Table 3 depicts the injury pattern among the subgroup of patients with self-inflicted gunshot wounds. In all age groups, the incidence of head injuries exceeded 50%. Patients with assault-related injuries most often presented with abdominal injuries (21.6%), followed by thoracic injuries (21.4%), extremity fractures (16.9%), and head trauma (15.9%). No statistically significant age-related trends could be identified among those patients.

The age-specific mortality rate in all patients sustaining gunshot wounds is demonstrated in Fig. 2 and shows a stepwise increase with advancing age ($p < 0.001$). Within the elderly age segment, the overall mortality was 37.4% ($n = 1,192$) and increased markedly with advancing age (28.5 versus 38.4 versus 55.4%; adjusted $p < 0.001$). Stratified by intent of injury, the mortality rate following assault-related and self-inflicted gunshot wounds likewise increased significantly with increasing age (adjusted $p < 0.001$) (Table 4). Patients suffering self-inflicted gunshot wounds had the highest mortality rate (59.7%), followed by patients with assault-related injuries (25.4%) and patients with unintentional injuries (9.3%) ($p < 0.001$).

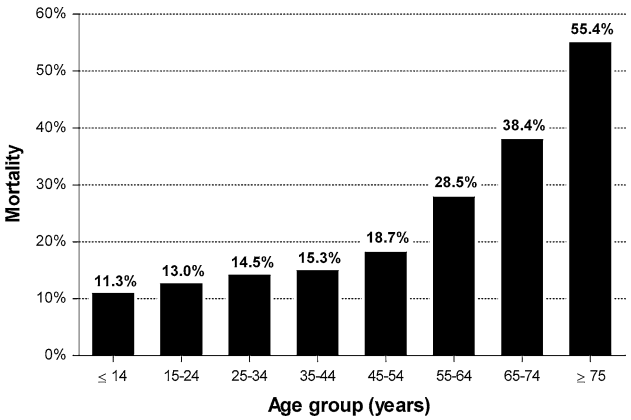

Fig. 2 Mortality rate in patients with gunshot wounds stratified by age groups

In patients surviving to discharge, intensive care unit (ICU) and hospital LOS steadily increased with age but peaked and remained constant among the elderly age groups (adjusted $p > 0.05$) (Fig. 3). Intensive care unit and hospital LOS were significantly prolonged for patients suffering self-inflicted gunshot wounds compared to patients with assault-related injuries and patients with unintentional injuries (all $p < 0.001$) (Table 4). Table 5 compares ICU and hospital LOS among survivors and nonsurvivors stratified by age. For nonsurvivors, overall ICU and hospital LOS was 2.94 ± 0.26 and 3.67 ± 0.39 days, respectively.

A significant decrease in the proportion of patients being discharged home was seen beginning at the age of 45 years, and a significant increase in those requiring rehabilitation or being discharged to nursing homes or skilled nursing facilities occurred at the same age cut-off (all adjusted $p < 0.001$) (Fig. 4).

Various factors potentially associated with fatal outcome in the elderly patients sustaining gunshot injuries were identified by bivariate analysis. Stepwise logistic regression analysis identified seven independent predictors for mortality (Table 6). An admission GCS ≤ 8, an ISS ≥ 16, hypotension on admission, age, self-inflicted injuries, and injuries sustained by assault were factors independently associated with death. The R^2 for this regression model was 0.69.

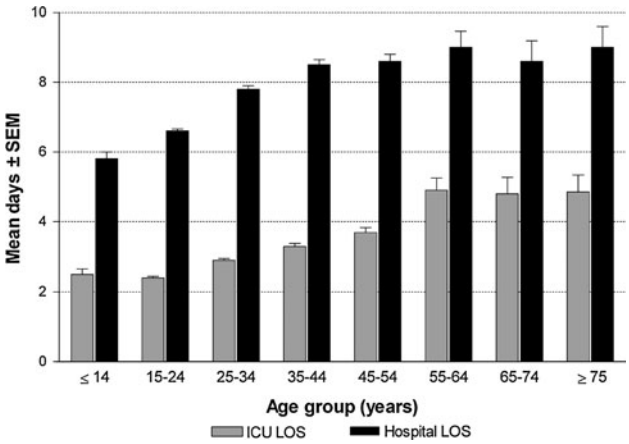

Fig. 3 Intensive care unit and hospital length of stay in patients with gunshot wounds stratified by age groups

Discussion

Elderly patients presenting to the hospital after sustaining an injury will continue to increase in number as the population ages. Although the majority of these patients are victims of blunt trauma, there is a small but significant percentage that sustain penetrating trauma. According to the NTDB, approximately 12 patients who are 55 years old or older are admitted every week to a trauma center in the United States after being shot. Five of every 12 of these

Table 4 Mortality and ICU and hospital LOS of survivors among elderly trauma patients with gunshot wounds stratified by intent of injury and age

Unintentional ($n = 462$)	Total	55–64 years ($n = 268$)	65–74 years ($n = 117$)	≥75 years ($n = 77$)	p Value	Adjusted p value*
Mortality	9.3% (43/462)	7.5% (20/268)	8.5% (10/117)	16.9% (13/77)	0.041	0.458
ICU LOS (days), mean ± SEM	2.50 ± 0.48	2.27 ± 0.60	1.86 ± 0.77	4.37 ± 1.64	0.226	0.466
Hospital LOS (days), mean ± SEM	6.05 ± 0.46	5.81 ± 0.56	5.39 ± 0.81	8.10 ± 1.64	0.157	0.401
Assault ($n = 1,261$)	Total	55–64 years ($n = 804$)	65–74 years ($n = 232$)	≥75 years ($n = 225$)	p Value	Adjusted p value**
Mortality	25.4% (320/1,261)	20.8% (167/804)	26.3% (61/232)	40.9% (92/225)	<0.001	<0.001
ICU LOS (days), mean ± SEM	4.95 ± 0.43	5.17 ± 0.55	4.75 ± 0.95	4.15 ± 0.79	0.698	0.632
Hospital LOS (days), mean ± SEM	9.57 ± 0.49	9.81 ± 0.62	8.83 ± 1.14	9.39 ± 1.01	0.745	0.889
Self-inflicted ($n = 1,269$)	Total	55–64 years ($n = 489$)	65–74 years ($n = 336$)	≥75 years ($n = 444$)	p Value	Adjusted p value***
Mortality	59.7% (757/1,269)	52.4% (256/489)	57.4% (193/336)	69.4% (308/444)	<0.001	<0.001
ICU LOS (days), mean ± SEM	5.48 ± 0.36	4.66 ± 0.64	4.98 ± 0.67	6.22 ± 0.55	0.144	0.093
Hospital LOS (days), mean ± SEM	12.47 ± 0.72	9.68 ± 0.83	11.35 ± 1.03	14.81 ± 1.36	0.009	0.006

* Adjusted for Glasgow Coma Scale (GCS) ≤ 8

** Adjusted for male gender, GCS ≤ 8, systolic blood pressure (SBP) <90 mmHg; injury severity score (ISS) ≥ 16, chest trauma

*** Adjusted for extremity trauma

Table 5 Hospital and intensive care unit LOS comparing survivors and nonsurvivors among elderly trauma patients with gunshot wounds

	Total (n = 3,190)	55–64 years (n = 1,676)	65–74 years (n = 727)	≥75 years (n = 787)	p Value*
ICU LOS, days (mean ± SEM)					
All patients	3.98 ± 0.19	4.42 ± 0.29	3.95 ± 0.38	3.10 ± 0.27	0.013
Survivors	4.65 ± 0.25	4.91 ± 0.35	4.05 ± 0.47	4.49 ± 0.49	0.372
Nonsurvivors	2.94 ± 0.26	3.25 ± 0.48	3.80 ± 0.66	2.07 ± 0.27	0.029
p Value**	<0.001	0.008	0.746	<0.001	
HLOS, days (mean ± SEM)					
All patients	7.37 ± 0.25	8.32 ± 0.39	6.82 ± 0.45	5.84 ± 0.46	<0.001
Survivors	9.55 ± 0.32	9.98 ± 0.46	8.58 ± 0.59	9.32 ± 0.60	0.203
Nonsurvivors	3.67 ± 0.39	4.12 ± 0.66	3.92 ± 0.62	3.01 ± 0.65	0.425
p Value**	<0.001	<0.001	<0.001	<0.001	

HLOS hospital length of stay

* Comparing age groups

** Comparing survivors and nonsurvivors

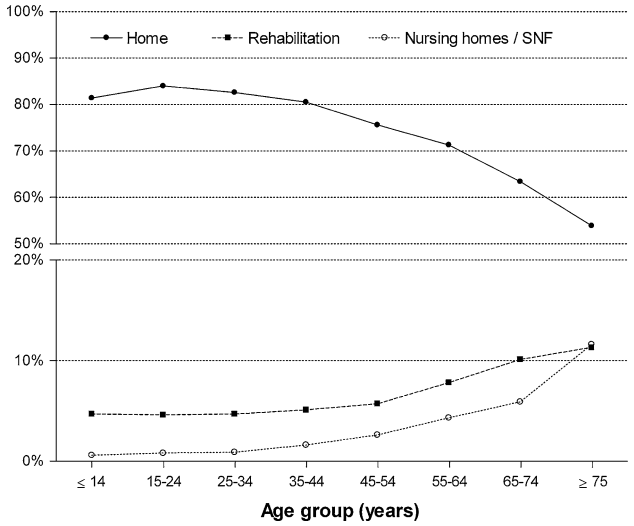

Fig. 4 Discharge disposition in patients with gunshot wounds stratified by age groups. *SNF* skilled nursing facility

admissions are related to a self-inflicted injury. These figures, however, likely underestimate the magnitude of this problem in the elderly population, as fatalities at the scene and admissions to non-trauma centers are not captured by the NTDB.

Suicide attempts in the elderly population are a well-recognized public-health problem in modern society. Common reasons provided in the literature include depression, chronic illness, or unmitigated pain [5]. According to the Centers for Disease Control and Prevention reporting data from 2005, the overall suicide rate in the United States is 11 per 100,000 people per year. But for those 65 years of age and older, this figure rises to 14 per 100,000 [6]. In urban settings, this number is even higher, depending on race and gender. In a study by Demetriades et al., Caucasian males over 65 years of age had the highest risk of suicide by penetrating trauma (29.5 per 100,000) in Los Angeles County [7]. The present study demonstrates an age-dependent relationship of suicide attempts to a penetrating mechanism. Almost 40% of gunshot injuries in elderly patients were self-inflicted, and a significant increase with progressing age was observed, with more than 55% of gunshot injuries being self-inflicted in patients ≥75 years. Within the self-inflicted injuries, by far the most commonly targeted body region was the head. Healthcare providers should be aware of this high proportion of self-inflicted injuries among elderly patients presenting with gunshot wounds, as this may be a high yield target for preventive measures.

Multiple studies have documented both short- and long-term outcomes after trauma to be worse in geriatric patients when compared with their younger counterparts [3, 4, 8–10]. Reduced physiologic reserve and a higher prevalence of pre-existing medical conditions are thought to account for these poor outcomes in the elderly population [5]. In a study by Kuhne et al. [9] the incidence of lethal multiple organ failure and overall in-hospital mortality increased significantly after the age of 56 years. Perdue et al. demonstrated geriatric status (≥65 years) in trauma patients to be associated with an almost 2.5-fold increased likelihood of early mortality and a 4.6-fold increased risk of late mortality (>24 h) [10]. However, most of these studies were performed in blunt trauma patients or did not differentiate between trauma mechanisms. Only a few small reports have investigated outcomes after penetrating trauma, primarily comparing elderly with younger trauma patients [3, 4, 11]. The results from studies by Roth et al. and Nagy et al. suggest that following penetrating trauma, older patients arriving alive to the hospital are as likely to survive as younger patients with similar injury severity, but at the expense of longer ICU and hospital stays [3, 4]. However, a recent investigation found that the crude mortality rate in penetrating trauma patients

Table 6 Predictors of mortality after stepwise logistic regression among elderly trauma patients with gunshot wounds

Step	Variable	Adjusted odds ratio (95% CI)	Adjusted p value	R^2
1	GCS $\leq$ 8	13.47 (10.35–17.53)	<0.001	0.581
2	ISS $\geq$ 16	5.50 (4.23–7.16)	<0.001	0.057
3	SBP < 90	5.27 (3.89–7.14)	<0.001	0.029
4	Age group	1.74 (1.50–2.03)	<0.001	0.018
5	Self-inflicted	2.80 (1.86–4.21)	<0.001	0.005
6	Assault	1.88 (1.24–2.87)	0.003	0.002
7	Extremity fracture	0.55 (0.32–0.95)	0.033	0.001

Variables entered into the equation: gender, GCS $\leq$ 8, SBP < 90, ISS $\geq$ 16, assault, self-inflicted, unintentional, head trauma, intracranial hemorrhage, abdominal trauma, extremity fracture, age group (55–64 versus 65–74 versus $\geq$75 years)

CI confidence interval

remains relatively constant until the age of 55 years, but starts to increase thereafter [11]. These findings are in line with the results of the present investigation. Although a steady increase in the mortality rate was observed among younger victims of gunshot wounds, a sharp rise in mortality was seen at the age of 55 years. Within the elderly age segment, the mortality rate further increased significantly. Similar to what has been observed in blunt trauma patients, the 55–64 years age group also appears to be the age group in which mortality begins to increase significantly following penetrating trauma. In patients surviving to discharge, ICU and hospital LOS increased in a stepwise fashion with increasing age but remained stable after the age of 55 years. These findings provide support for the recommendations made by previous authors for early aggressive monitoring and intervention in managing elderly trauma victims [12–14] At our center, patients >65 years old, not requiring operative intervention, are transferred immediately to the surgical ICU, bypassing the observation area. All imaging and therapeutics are expedited, and these patients are aggressively monitored throughout their hospital course.

For surviving patients, a significant increase in patients being discharged to nursing homes or rehabilitation facilities and a decrease in patients being discharged home was observed beginning at the age of 45 years. Unfortunately, the data available in the NTDB do not allow for the analysis of more comprehensive long-term outcomes. For blunt trauma, it has been shown that an increased risk of death in elderly trauma patients persists for up to six years from the time of hospitalization for injury [15]. Furthermore, Inaba et al. demonstrated that trauma has a significant impact on long-term quality of life in geriatric trauma survivors. Most importantly, a loss of independence was seen at long-term follow-up [16]. Similar data, specifically investigating long-term outcomes after penetrating trauma in the elderly patient population were not available in the NTDB, and further research is warranted.

Patients who were treated for self-inflicted gunshot wounds had a significantly higher mortality rate than victims of assault or patients sustaining unintentional injuries. Likewise, patients surviving self-inflicted gunshot wounds required longer ICU and overall hospital stays than survivors of assault and unintentional injuries. These findings are in line with previous studies, showing that intentional injuries are associated with a significantly higher risk of death and residual disability and that these patients utilize higher levels of healthcare resources than patients suffering unintentional injury [17, 18].

We identified several independent risk factors for death in elderly patients sustaining gunshot injuries, including a low admission GCS score, an ISS $\geq$ 16, and hypotension on admission. Advancing age was shown to be associated with worsened outcome and was the fourth most important independent risk factor. Additionally, in concordance with the previously mentioned studies, the intent of injury was seen to represent a significant risk factor for death [17, 18]. In contrast, extremity fractures were independently associated with better outcomes. This is most likely because the vast majority of patients suffering an extremity injury (75.1%) sustained an isolated extremity trauma without concomitant life-threatening intrathoracic, intra-abdominal, or intra-cranial injury.

Although this is one of the largest studies examining penetrating injuries in the elderly age segment, there are several limitations. As this was a retrospective study, missing data and reporting discrepancies are to be expected, especially when analyzing large database such as the NTDB. However, all of the variables used in this study did not have more than 10% missing data points. Furthermore, the data in the NTDB do not accurately include information on pre-existing medical conditions or in-hospital complications, and thus such information was not available for analysis. Therefore, the impact of co-morbidities and medications in these patients would be critical to capture in any further prospective analysis of this problem.

In conclusion, injury caused by firearms is not uncommon in the elderly patient population and is primarily due to self-inflicted gunshot wounds to the head. These patients

sustain a high burden of injury and a high rate of mortality, which increases with advancing age. Similar to patients suffering blunt trauma, elderly victims of gunshot wounds represent a significant burden on healthcare resources with a prolonged ICU and hospital LOS compared to their younger counterparts. Even after discharge, these patients frequently require further allocation of healthcare resources with transfer to nursing facilities and rehabilitation centers.

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