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Prior Emergency Department Utilization as a Predictor for Severe Penetrating Trauma: A Retrospective Cohort Study

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An abstract of
a thesis submitted to the Faculty of the
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Abstract

Prior Emergency Department Utilization as a Predictor for Severe Penetrating Trauma: A Retrospective Cohort Study

By Alexandra Reitz

Introduction

Homicide and suicide are leading causes of mortality among adults under the age of 65. While extensive research has been conducted on healthcare utilization subsequent to severe penetrating trauma events, there is a dearth of information on healthcare utilization prior to these events. This study examined emergency department (ED) utilization patterns to determine if prior ED visits for injury were a risk factor for severe penetrating trauma.

Methods

This retrospective cohort study examined the ED visit records of 215,800 patients with 489,800 ED visits and 3,322 trauma registry patients from November 2010 to February 2015 at a large, urban hospital with a Level I trauma center. Data analysis was conducted using logistic regression and Cox proportional hazard models.

Results

Among 215,800 ED patients, 224 patients with prior ED visits experienced severe penetrating trauma, accounting for 7% of all penetrating trauma registry patients. In a bivariate model, prior ED visits for injury (Odds Ratio (OR) 2.17, Confidence Interval (CI) 1.67 to 2.83, $p< 0.0001$) were significantly associated with severe penetrating trauma. After adjustment for age, gender, employment, insurance, high utilization, and admission status, prior ED visits for injury continued to be associated with severe penetrating trauma (OR 1.60, CI 1.21 to 2.10, $p=0.001$). Cox proportional hazard models were used to estimate hazard ratios (HR) for factors associated with time to a penetrating trauma event following a patient's last ED visit. After adjusting for age, gender, employment status, admission status, high utilization, and insurance status, patients with an injury diagnosis at their last ED visit had a HR of 1.43 (CI 1.07-1.93, $p=0.016$).

Conclusions

After adjusting for confounders, a previous ED visit for injury remained a significant risk factor for severe penetrating trauma. Patients with a last ED visit for injury also had an elevated rate of time to penetrating trauma. These findings suggest a need for targeted violence intervention programs and improved ED injury surveillance.

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Introduction

Homicide and suicide are leading causes of mortality among adults under the age of 65 in the United States.[1] Most homicides and suicides are the result of penetrating trauma due to firearms and stabbings. While the occurrence of firearm deaths has declined since the early 1990s, there is increasing evidence that the incidence of nonfatal firearm injuries is on the rise.[2-4] More than 67,000 persons experience a firearm injury annually. Due to their frequency and severity, these injuries contribute significantly to healthcare costs. From 2010 to 2012, firearm injuries resulted in an estimated $48 billion annually in medical and work loss costs.[2]

A number of individual, interpersonal, community, and societal characteristics are proven risk factors for violence. Research has demonstrated that these risk factors are consistent for both victims and perpetrators of interpersonal violence.[5,6] Individual risk factors include male gender, substance use, and emotional distress.[7] Interpersonal risk factors include exposure to a victim or perpetrator of violence and low levels of family cohesion.[5,8-10] Community risk factors include residing in environments with concentrated disadvantage, drug markets, and weapon availability.[7,11-13] On a national level, the United States remains an outlier in its rates of homicide when compared to other Organisation for Economic Co-operation and Development (OECD) nations.[14]

Stark disparities in severe penetrating trauma exist. The overwhelming majority of patients impacted by severe penetrating trauma are male. Rates of homicide and suicide in males are approximately four times higher for men than for women.[7] In addition, there are significant racial disparities. African-American and American Indian or Alaskan Natives have rates of homicide that far exceed those of other races or ethnic backgrounds.[7] In 2015, firearm homicides accounted for 16.0% of years of potential life lost before age 65 among black males compared to only 2.1% among white males.[1]

Although certain demographic groups are at higher risk for penetrating trauma, it is critical to note that risk is not homogenously distributed among individuals within minority populations. In communities and areas with high levels of violence, often times an exceedingly small number of individuals drive serious violence.[5,15,16] In addition, in communities with high gun violence, firearm injury incidence is often concentrated in specific "hot spot" locations.[17-20] There is also growing evidence that victims of firearm violence in a community often share a social network.[21-23] Consequently, violence prevention in high-risk individuals can help disrupt a cycle of violence within a wider social network.

Severe penetrating trauma is preventable; however, one of the greatest challenges surrounding violence prevention is the lack of nonlethal violence surveillance. Most violence is notoriously underreported, particularly to law enforcement.[14] Thus, the medical system has a unique opportunity to identify high-risk individuals and intervene with proven prevention methods. The National Network of Hospital-based Violence Intervention Programs (NNHVIP) currently has a network of thirty organizations who utilize evidence-based methods to prevent violence.[24] Most of these programs focus on severely injured patients at high-risk for trauma recidivism in urban areas with a high burden of violence. Many programs have demonstrated success. In San Francisco, a hospital-based violence program targeting victims of intentional injury, who were admitted for their injuries, was followed by a fourfold reduction in injury recidivism.[25] In addition, these programs have demonstrated cost-effectiveness within hospital systems as well as wider cost benefits.[26,27]

Based on the success of these intervention programs, we sought to identify characteristics of emergency department patients who could potentially benefit from a violence prevention program. Our objective was to determine which factors during antecedent emergency department visits may serve as predictors of subsequent severe penetrating trauma. The specific risk factors of interest in this study included prior emergency department (ED) visits for injury along with ED visit frequency and admission status.

Sample and Study Design

This retrospective cohort study was approved by the Institutional Review Board (IRB) at Emory University as well as the Research Oversight Committee at Grady Memorial Hospital. The IRB granted a waiver of informed consent. Data were obtained from the electronic medical record and trauma registry for all emergency department visits and penetrating trauma entries at an urban, public hospital with a Level I trauma center from October 2010 to March 2015. ED visits associated with a concomitant severe penetrating event were excluded from the study, and recidivist episodes of penetrating trauma on the registry were excluded.

Measurements

Patient demographic characteristics, primary reason for ED visit, and severe penetrating trauma events were ascertained from electronic medical records. The primary outcome was defined as an entry on the trauma registry for penetrating trauma consistent with the standards set forth by the National Trauma Data Standard: Data Dictionary.[28] For inclusion on the trauma registry patients must have an injury with an International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) diagnostic code from 800-959.9 along with a hospital admission of at least twenty-four hours, a fatal event, or a transfer. External cause codes are used to assign an injury to the category penetrating trauma.

Primary diagnosis for an ED visit was assigned according to ICD-9-CM codes and relevant text entries in the primary diagnosis field. Injury exposure was defined for ICD-9-CM codes from 800 to 999.99 or if the primary reason for the visit included the text entry "injury." While some studies include only the ICD-9 codes 800 to 959 for injuries, for the purpose of this study, a wider range of injuries such as poisoning were considered relevant.

Patients with entries on the trauma registry for penetrating trauma were matched to emergency department visits using medical record numbers in order to identify ED patients with the outcome of interest. This form of matching is likely imperfect. While the trauma registry data was

largely reliable and complete, the ED visit data contained missing values, particularly for patients who left without being seen. Some demographic characteristics, such as age and gender, were assigned using complete fields from other ED visits. High ED utilization was defined as four or more ED visits during the study period. Four visits was chosen based on it representing the top 10% of ED utilizers. Race was not used as a variable in this study since the data obtained from the electronic medical record did not include this patient information. Including race would have had a limited impact on our study since the overwhelming majority of patients at our study site identify as African-American or black.

Statistical Analysis

Descriptive statistics were calculated using the total study population. Logistic regression was used to assess certain characteristics association with penetrating trauma. Certain variables such as age, employment, insurance status, and admitting status were assigned from a patient's last ED visit during the study. The logistic regression model also assigned cumulative values to the following variables: prior ED visits for an injury, high utilization, and ever being uninsured. In our final adjusted model, covariates considered to confound the relationship between prior ED visits for injury and severe penetrating trauma included age, gender, insurance status, employment status, high utilization, and admitting status. Cox proportional hazard models were used to estimate the hazard ratios (HR) for factors associated with time to severe penetrating trauma after a patient's last ED visit. All statistical comparisons were performed with SAS version 9.4 (SAS Institute, Inc., Cary, NC). All tests were two-sided and p-values of less than 0.05 were considered significant during statistical analysis.

Results

A total of 215,800 patients were included in this study. Descriptive characteristics of all study participants are summarized in Table 1. Patients with ED visits for injury reasons tended to be

male and had high rates of unemployment. The majority of patients in the study population were uninsured (63%). Patients with a primary diagnosis of injury were more likely to be younger than 35 years of age (45%). A total of 224 patients had severe penetrating trauma following an ED visit. These 224 patients accounted for 7% of the total 3,322 penetrating trauma patients on the trauma registry during the study period. As seen in Table 2, the majority of these patients were male with a penetrating injury due to a firearm or piercing. The average Injury Severity Score (ISS), an anatomical scoring system used for trauma patients, was 8.55 (Standard Deviation=9.17). Toxicology results demonstrated that 27% of the patients tested positive for alcohol or drugs at the time of the trauma event despite a significant number of patients not being tested. 5% of these patients died from their penetrating trauma injuries.

As seen in Table 3, bivariate analysis demonstrated patients with a prior ED visit for injury (Odds Ratio (OR) 3.17, Confidence Interval (CI) 1.67-2.83, $p<0.0001$) had increased odds of penetrating trauma. Male patients had 7.33 times greater odds of penetrating trauma than female patients (OR 7.34, CI 4.80 to 11.19, $p<0.0001$). Patients 35 years old and above had odds of penetrating trauma at least 50% less than patients between 15 and 35 years of age. Employed patients were also at a reduced odds of penetrating trauma (OR 0.44, CI 0.31 to 0.63, $p<0.0001$) along with patients who had a prior ED visit that did not require hospital admission (OR 0.45, CI 0.28-0.74, $p=0.0017$). The odds of penetrating trauma for patients with a history of being uninsured was 3.35 times higher than patients with a history of insurance (OR 3.35, CI 2.44 to 4.85, $p<0.0001$). Finally, patients with high ED utilization, defined as four or more ED visits prior to outcome or censoring, had increased odds of penetrating trauma (OR 1.56, CI 1.10-2.20, $p=0.0122$).

In a selected multivariate model, after adjusting for the covariates age, gender, employment status, insurance status, high utilization, and admitting status, a prior ED visit for injury continued to be an independent risk factor for severe penetrating trauma (OR 1.60, CI 1.21 to 2.11, $p=0.001$). A Cox proportional hazard model was designed to estimate the difference in the hazard rates of patients with a last ED visit for injury compared to those without, controlling for confounders.

Figure 1a illustrates unadjusted Kaplan-Meier curves of time to severe penetrating trauma by injury diagnosis at last ED visit. Among patients with an injury diagnosis at their last ED visit, the proportion of patients experiencing penetrating trauma was nearly twice as high after one year compared to patients without an injury diagnosis. As seen in Figure 1b, a last ED visit for injury is continued to be associated with an elevated hazard ratio, even among only patients not admitted to the hospital at the time of their ED visit. In an adjusted model including, gender, employment status, insurance status, and admitting status, a last ED visit for injury had a hazard rate 1.53 times higher than patients without an injury diagnosis as seen in Table 4.

Discussion

Our results suggest that prior ED visits for injury are associated with increased odds of future penetrating trauma compared to patients without prior ED visits for injury. Even after adjusting for potential confounders, prior ED visits for injury remained significantly associated with severe penetrating trauma. In addition, patients with a last ED visit for injury had an elevated hazard rate of penetrating trauma compared to patients with a non-injury visit.

Previous studies exploring trauma recidivism and risk factors have largely focused on hospitalized patients.[29-31] Our study sought to expand this research by identifying risk factors for penetrating trauma present among a general ED population. Interestingly, our analysis showed among patients not admitted to the hospital, those with a last ED visit for injury had a higher rate of penetrating trauma than uninjured patients. Thus, lower acuity injuries are associated with a heightened risk of penetrating trauma. Therefore, these findings indicate that ED visits for less severe injuries can help identify high-risk populations. Our study's other findings were largely consistent with earlier literature on established risk factors for penetrating trauma. Like other studies, our results demonstrated being young, male, unemployed, and uninsured served as significant risk factors for penetrating trauma.[32]

One limitation of our study is our study population was restricted to the ED population of a single, large public hospital. As Kaufman et al. demonstrated many patients with recurrent violent injury access numerous hospitals with 59% of patients using a different hospital for a second injury.[33] Thus, it is likely that patients had ED visits and potentially penetrating trauma events outside of our study site. In addition, our study relied on passively collected data from ED operations, which provided us a large study sample but at times resulted in poor completion of data fields and limited quality control.

Another limitation of our study is the inability to define features of the injuries associated with future penetrating trauma, such as intentionality. It is likely that patients with intentional injury due to interpersonal violence are at higher risk of penetrating injury compared to patients with unintentional injury. However, our limited dataset hindered any exploration of intentionality. Still, Haider et al. showed both intentionally and unintentionally injured trauma registry patients had equivalent rates of mortality, although those intentionally injured were at a higher risk of violent death.[34] In addition, Rowhani-Rahbar et al. demonstrated that unintentional injury, in addition to intentional injury, was associated with future violence-related arrest, suggesting that our use of injury as a broad category likely captures a high risk group.[29]

Our findings suggest the need for improved injury surveillance in the ED. Currently, it is exceedingly difficult to determine the incidence of violence due to underreporting and fractured reporting systems.[14] This lack of coordination in reporting contributes to the lack of comprehensive, coordinated responses to violence. An innovative program in Cardiff, Wales monitored violent injuries in the ED and later shared anonymized data with relevant local authorities. This model not only created improved surveillance of community violence, it was also associated with a decrease in violence.[35] Thus, better surveillance of violence in the ED and a coordinated response with other local agencies could improve community-wide measures of violence. In addition, while current violence intervention projects tend to focus on patients hospitalized with severe injuries,[25,36] our

study indicates that there is also a need for interventions targeted at a high-risk group with lower acuity injuries.

Conclusion

This study demonstrates that after adjusting for confounders, a previous ED visit for injury remained a significant risk factor for severe penetrating trauma. In addition, patients with a last ED visit for injury had an elevated rate of penetrating trauma compared to patients with non-injury ED visits. These findings suggest a need for hospital-based injury surveillance to detect intentional violence and implement evidence-based and cost-effective violence prevention programs.

Table 1. Demographics and clinical characteristics of patients with ED visits to Grady Memorial Hospital from October 2010 to March 2015

	All Patients Total N=215,800 N (%)	**Patients with Penetrating Trauma** Total N=224 N (%)	**Patients without Penetrating Trauma** Total N=215,576 N (%)
Gender			
Male	114,683 (53%)	200 (89%)	114,483 (53%)
Female	100,840 (47%)	24 (11%)	100,816 (47%)
Declined	277 (<1%)	-	277 (<1%)
Age			
<15	2,676 (1%)	-	2,676 (<1%)
15-24	31,506 (15%)	58 (26%)	31,448 (15%)
25-34	42,638 (20%)	88 (39%)	42,550 (20%)
35-44	33,710 (16%)	31 (14%)	33,679 (17%)
45-54	37,164 (17%)	25 (11%)	37,139 (17%)
55-64	27,602 (13%)	16 (7%)	27,856 (13%)
>65	17,561 (8%)	6 (3%)	17,555 (8%)
Unknown	22,943 (11%)	-	22,943 (11%)
Employed			
Yes	63,975 (30%)	36 (16%)	63,939 (30%)
No	136,643 (63%)	175 (78%)	136,468 (63%)
Unknown	15,182 (7%)	13 (6%)	15,169 (7%)
Insured			
Yes	79,064 (37%)	33 (15%)	79,031 (37%0
No	136,736 (63%)	191 (85%)	136,545 (63%)
Admitted			
Yes	33,089 (15%)	17 (8%)	33,072 (15%)
No	182,711 (85%)	207 (92%)	182,504 (85%)
Previous ED Visit for Injury			
Yes	63,134 (29%)	106 (47%)	63,028 (29%)
No	152,666 (71%)	118 (53%)	152,548 (71%)

Table 2. Demographics and clinical characteristics of 224 patients with severe penetrating trauma and prior ED visits at Grady Memorial Hospital from October 2010 – March 2015

Gender	N (%)	***Discharge Status***	N (%)
Male	201 (90%)	Alive	212 (95%)
Female	23 (10%)	Deceased	12 (5%)
Alcohol Toxicology		***Type of Penetrating Injury***	
Positive	61 (27%)	Firearm	130 (58%)
Negative	106 (47%)	Cut/Pierce	45 (20%)
Not Tested	57 (25%)	Other	49 (22%)
Drug Toxicology		***Average ISS Score***	Mean (SD)
Positive	61 (27%)		8.55 (9.17)
Negative	20 (9%)		
Not Tested	143 (64%)		

Table 3. Results of bivariate and multivariate logistic regression analysis of an ED cohort of patient's risk factors for severe penetrating trauma

Variables	**Unadjusted OR (95% CI)** N=215,800	p-value	**Adjusted OR (95% CI)** N= 181,515	p-value
Male Gender[a]	7.34 (4.81-11.21)	<.0001	5.74 (3.74-8.81)	<.0001
Age[a]				
15-24	Reference		Reference	
25-34	1.12 (.80-1.56)	0.4990	1.00 (0.70-1.41)	0.9760
35-44	0.50 (0.32-0.77)	0.0020	0.45 (0.28-0.70)	0.0005
45-54	0.37 (0.23-0.58)	<.0001	0.34 (0.21-0.55)	<.0001
55-64	0.31 (0.18-0.55)	<.0001	0.32 (0.18-0.57)	0.0001
>65	0.19 (0.08-0.43)	<.0001	0.40 (0.17-0.96)	0.0402
Employed[a]	0.44 (0.31-0.63)	<.0001	0.49 (0.34-0.71)	0.0001
Ever Uninsured	3.35 (2.31-4.85)	<.0001	2.54 (1.70-3.80)	<.0001
Admitted	0.45 (0.28-0.74)	0.0017	0.52 (0.31-0.88)	0.0140
High ED Utilization	1.56 (1.10-2.20)	0.0122	1.32 (0.92-1.90)	0.1293
Prior ED Visit for Injury	2.17 (1.67-2.83)	<.0001	1.60 (1.21-2.11)	0.0010

[a]Unadjusted calculated with N=215,523 for gender, N=192,857 for age, and N=200,618 for employment due to missing values.

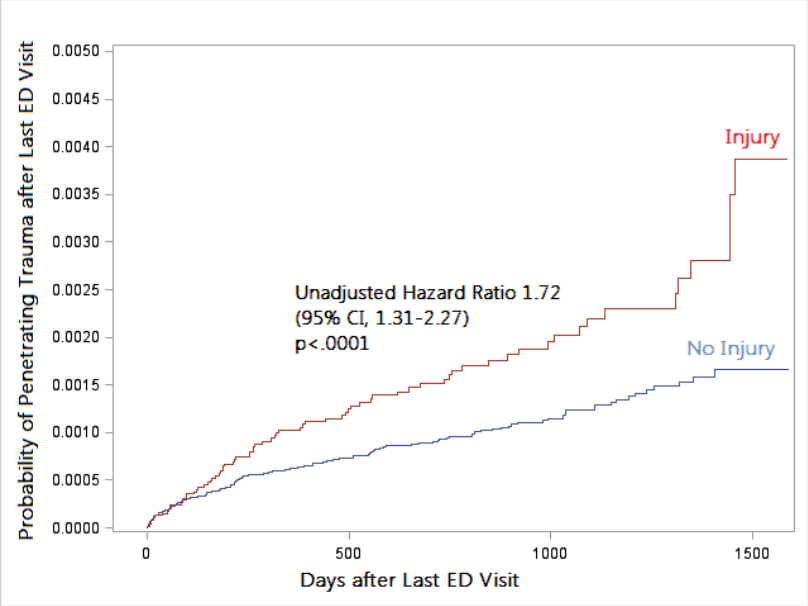

Figure 1a. Unadjusted Kaplan-Meier curve of probability of severe penetrating trauma by last ED visit for injury status for all cohort patients, censored at time of study conclusion

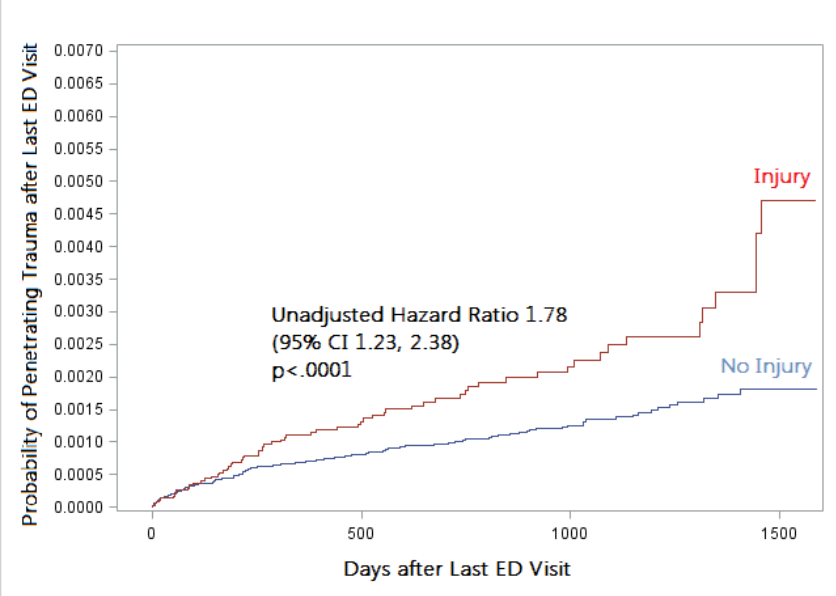

Figure 1b. Unadjusted Kaplan-Meier curve of probability of severe penetrating trauma by last ED visit for injury status among patients not admitted at their last ED visit

Table 4. Hazard ratios for analysis of the association between a patient's last ED visit for injury and severe penetrating trauma

Variables	**Unadjusted HR (95% CI)** N=215,800	p-value	**Adjusted HR (95% CI)** N= 181,515	p-value
Male Gender[a]	7.31 (4.78-11.16)	<.0001	6.01 (3.92-9.23)	<.0001
Age				
15-24	Reference	-	Reference	-
25-34	1.13 (0.81-1.58)	0.460	1.03 (0.73 1.46)	0.859
35-44	0.50 (0.33-0.78)	0.002	0.45 (0.29-0.72)	0.0007
45-54	0.38 (0.24-0.60)	<.0001	0.35 (0.21-0.56)	<.0001
55-64	0.34 (0.19-0.59)	0.0001	0.33 (0.19-0.58)	0.0001
>64	0.20 (0.09-0.46)	0.0002	0.32 (0.13-0.76)	0.010
Employed[a]	0.44 (0.31-0.63)	<.0001	0.45 (0.31-0.65)	<.0001
Uninsured	1.86 (1.38-2.50)	<.0001	1.37 (0.99-1.89)	0.053
Admitted	0.46 (0.28-0.76)	0.002	0.47 (0.28-0.79)	0.004
High ED Utilization	2.27 (1.60-3.21)	<.0001	2.73 (1.90-3.93)	<.0001
Prior ED Visit for Injury	1.72 (1.31-2.27)	<.0001	1.43 (1.07-1.93)	0.016

[a]Unadjusted calculated with N=215,523 for gender, N=192,857 for age, and N=200,618 for employment due to missing values.

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