Comparison of Injury Severity and Resource Utilization in Pediatric Firearm and Sharp Force Injuries

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A thesis

submitted in partial fulfillment of the

requirements for the degree of

Master of Science

University of Washington

2019

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Program Authorized to Offer Degree:

Health Services

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Abstract

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Importance: Pediatric firearm injuries are a serious and growing public health problem. Firearm injuries have a high case-fatality, but we lack a full knowledge of their injury severity and healthcare utilization compared to other penetrating injuries, especially among critically injured children.

Objective: Describe resource utilization, injury severity, and short-term clinical outcomes for pediatric firearm injuries and compare those to non-firearm penetrating sharp force injuries in children.

Design: Retrospective cohort study utilizing the National Trauma Data Bank (NTDB) data years 2007-2016.

Setting: Multicenter database study.

Participants: Encounters for firearm injury or cut/pierce injury in children 17 years or younger.

Exposure: Firearm injury encounters were compared to cut/pierce injury encounters.

Outcomes: Intensive care unit (ICU) admission, hospital and ICU length of stay (LOS), and injury severity score (ISS).

Results: We identified 25,155 encounters for firearm injuries and 21,270 encounters for cut/pierce injuries. The majority of firearm injuries and cut/pierce injuries were suffered by males (85.8% vs. 74.6%) and adolescents aged 15-17 (74.8% vs. 51.2%). A greater proportion of those with firearm injuries were African-American (61.3%) than those with cut/pierce injuries (31.1%). A greater proportion of firearm injuries (30.5%) than cut/pierce injuries (12.8%) were admitted to the ICU. Firearm injuries resulted in a higher mean Injury Severity Score (ISS), longer mean hospital and ICU length of stay (LOS) compared to cut/pierce injuries. Firearm injuries accounted for 126,027 hospital days and 39,255 ICU days while cut/pierce injuries accounted for 58,705 hospital days and 8,353 ICU days. After adjusting for age, sex, year, and hospital, firearm injuries were 2.3 (95% CI: 2.1-2.5) times more likely to require ICU admission and were associated with higher ISS scores compared to cut/pierce injuries, even among critical injuries. Multinomial logistic regression demonstrated higher risk of prolonged hospital (RRR 4.11 95%CI: 3.46-4.89) and ICU LOS (RRR 2.16 95%CI: 1.91-2.45) for firearm injuries compared to cut/pierce injuries.

Conclusions and Relevance: Pediatric firearm injuries carry a greater injury severity and health care utilization compared to other penetrating injuries even among critical injuries, demonstrating that mechanism of injury is an important consideration in pediatric penetrating trauma. This highlights the importance of public health measures to reduce the risk of pediatric firearm injuries.

Objectives

Firearm injuries and deaths constitute a serious public health problem in the United States. In children and adolescents up to 19 years of age, firearm related injuries are the second leading cause of death, accounting for 3,155 deaths and 17,223 non-fatal injuries in 2016 and 3,443 deaths and 18,227 non-fatal injuries in 2017.[1-3] Adolescent unintentional injury deaths, homicide rates, and suicide rates from firearms have increased significantly in recent years with the years 2013-2016 showing increased death rates in all three areas in as well as an increase in total firearm injuries[4-12] Pediatric firearm injuries and deaths disproportionately impact certain populations. The burden of violent assault deaths and injuries from firearms falls disproportionately on male, African-American and Hispanic, and socioeconomically disadvantaged persons and communities. Conversely, the burden of self-inflicted firearm suicide is higher among white children.[1,5,11-22]

Despite our growing knowledge of the epidemiology and sociodemographic factors associated with pediatric firearm mortality, less attention has been focused on children and adolescents who sustain firearm injuries not initially fatal at the scene of injury, especially those who are critically injured from firearm injuries. This population is potentially responsible for a large burden of healthcare utilization and morbidity.[23,24] Previous studies have focused on clinical outcomes mainly in the context of mortality, or compared outcomes based on intent or race.[13,16,17,19,25-27] Additionally, we lack a full understanding of the potentially distinct consequences of firearm injuries due to their typically severe nature. Previous studies have documented the high case fatality associated with firearm injuries but lack a robust comparison with other penetrating trauma mechanisms in terms of indicators of severity among children and adolescents.[28,29]

We sought to determine and quantify resource utilization, short-term clinical outcomes, and injury severity in pediatric firearm injuries requiring medical care, through examining non-fatal firearm injuries as well as those injuries that are ultimately fatal but survive to hospital presentation. We sought particularly to enhance the understanding of those firearm injuries resulting in critical injury. We compared these injuries with other non-firearm penetrating sharp force injuries to contextualize the outcomes for firearm injuries.

Methods

We conducted a retrospective cohort study using the National Trauma Data Bank (NTDB) for the years 2007-2016. The NTDB is an encounter level trauma registry with voluntary participation developed by the American College of Surgeons in 1989 and represents the largest trauma registry in the United States. In 2016, 780 hospitals contributed pediatric data with 36 of these hospitals constituting pediatric only facilities and 306 hospitals with an association with a pediatric hospital. Although not comprehensive, this captures the majority of pediatric trauma encounters in the United States. The selected years for analysis in this study represent the most recently available 10 years of data from the NTDB. This study was exempt from the University of Washington institutional review board as all data were de-identified.

Injury encounter identification was performed through the use of external causes of injury codes (E codes). The cohort was restricted to encounters with E codes for primary injury mechanism of “Firearm” as the primary population of interest and “Cut/Pierce” as the comparison population. Encounters with both “Firearm” and “Cut/Pierce” E codes were excluded from analysis. The cohort was restricted to encounters for patients younger than 18 years of age. We also excluded encounters that were coded as “transferred” so as to eliminate the

risk of double counting in de-identified encounter level data. Encounters requiring admission to the hospital as well as those encounters that were treated in the emergency department and discharged were included.

Demographic information including age, race, sex, and insurance status was collected for each encounter in addition to injury intent mechanism. Clinical variables including intensive care unit (ICU) admission which was defined as any length of stay (LOS) in the ICU, hospital and ICU LOS, ventilator use, and injury severity score (ISS) were also collected. The ISS is an anatomic scoring system utilized in trauma patients to predict and risk stratify morbidity and mortality. The score ranges from 0 to 75 with injuries scored <9 considered minor, 9-15 considered moderate, and >15 considered severe with 75 deemed unsurvivable[30,31]

Descriptive analyses were performed to obtain mean, frequency, and percentage for demographic and clinical characteristics for all injuries as well as critical injuries, defined as injuries resulting in ICU admission. Age categories were chosen in accordance with CDC age categories for pediatrics.

Injury encounters for “Firearm” injury mechanisms were compared to injury encounters for “Cut/Pierce” injury mechanisms utilizing regression models controlling for age, sex, year, and clustering by hospital for primary outcome variables of interest of ICU admission, hospital and ICU LOS, and ISS. Specifically, a binomial regression model was used to compare the probability of ICU admission between the two groups. Generalized linear regression model with gamma family and log link was used to compare ISS between the two groups. Multinomial logistic regression model was used to compare risk for distinct categories of hospital length of stay and ICU length of stay between the two groups using relative risk ratios (RRR) and their corresponding 95% confidence intervals.

We chose to perform a multinomial logistic regression for hospital and ICU LOS as we hypothesized that hospital and ICU LOS consisted of distinct subcategories reflecting inherently and qualitatively different injury outcomes and whose relationship to the injury mechanism were not inherently ordered. As a result, we hypothesized that the relationship between injury mechanism and LOS would be best described by a non-linear, non-ordinal function which would yield a more comprehensive and richer understanding of the underlying relationship. Distinct categories of length of stay were chosen after consideration of clinical relevance and to assure adequate sample size within each category and subcategory of hospital and ICU LOS by age category to allow for model convergence.

We conducted sensitivity analyses to evaluate the stability of effects observed after restricting the sample in two ways and performing and additional analysis for LOS. First, we restricted the sample to exclude those injury encounters with ISS equal to 75, which is deemed unsurvivable and therefore would capture those patients likely to die of their injuries and potentially represent a large burden of injury severity. Second, we restricted the sample to exclude those injury encounters whose mechanism was coded as self-inflicted, as many self-inflicted firearm injuries are suicide attempts in the form of close-range shots to the head and face. We hypothesized that these self-inflicted injuries may represent a very high injury severity and mortality risk among those patients who survived to hospital admission. Finally, we conducted a sensitivity analysis to evaluate the stability of the effect observed for multinomial logistic regression modeling of hospital and ICU LOS by performing a Poisson regression with robust standard errors. All statistical analyses were performed using Stata/SE version 14.2 (StataCorp) and graphs generated using Exel version 16.24 (Microsoft).

Results

Over the 10-year period, we identified 25,155 encounters for firearm injuries and 21,270 encounters for cut/pierce injuries. A greater proportion of those with firearm injuries (85.8%) than those with cut/pierce injuries (74.6%) were male. The majority of firearm injuries and cut/pierce injuries were sustained by adolescents aged 15-17 (74.8% and 51.2%, respectively). A greater proportion of those with cut/pierce injuries were children aged 0-4 years, 5-9 years, and 10-14 years than those with firearm injuries. A greater proportion of those with firearm injuries were African-American (61.3%) than those with cut/pierce injuries (31.1%). A greater proportion of firearm injuries were assault (79.9%) than cut/pierce injuries (40.6%). A majority of cut/pierce injuries were unintentional (50.5%) **(Table 1)**.

Firearm injuries resulted in mean ISS of 10.9 compared with 4.6 for cut/pierce injuries. Mean hospital LOS was 5.0 days for firearm injuries and 2.8 days for cut/pierce injuries. In isolating the subcohort of critically injured children, we identified 7,682 firearm injuries which required ICU care (30.5%) and 2,712 cut/pierce injuries which required ICU care (12.8%). Mean ISS for critical injuries was 17.2 for firearm injuries and 11.0 for cut/pierce injuries. Mean ICU LOS was 5.1 days for critical firearm injuries and 3.1 days for critical cut/pierce injuries. In total for similar number of firearm injuries and cut/pierce injuries over the period of this study, firearm injuries accounted for a total of 126,027 hospital days and 39,255 ICU days while cut/pierce injuries accounted for 58,705 hospital days and 8,353 ICU days. Of critical injuries, 44.4% of firearm injuries required mechanical ventilation and 25.8% of cut/pierce injuries required mechanical ventilation (**Table 2**).

Multivariable logistic regression model adjusting for age, sex, data year, and hospital, demonstrated firearm injuries were 2.3 times more likely to require ICU admission compared to

cut/pierce injuries (95%CI: 2.1-2.5). Generalized linear regression adjusting for age, sex, data year, and hospital demonstrated firearm injuries compared to cut/pierce injuries were associated with a 6.7-point higher ISS score for all injuries (95%CI: 6.1-7.2), 6.9-point higher ISS for critical injuries (95%CI: 6.2-7.6), and a 4.4-point higher ISS score for non-critical injuries (95%CI: 3.9-4.9) (**Figure 1**).

Multinomial logistic regression adjusting for age and sex revealed distinct patterns for LOS. Firearm injuries were less likely to have hospital LOS of 2-3 days (RRR=0.84; 95% CI: 0.78-0.92) and were more likely to have hospital LOS of 10+ days (RRR=4.11; 95% CI: 3.46-4.89) compared with cut/pierce injuries. Critical firearm injuries were more likely to have ICU LOS of 4+ days (RRR=2.16; 95% CI: 1.91-2.45) compared to cut/pierce injuries (**Figure 2**).

Sensitivity analysis revealed similar estimates to primary analysis and resulted in the same conclusions for all outcomes. Firearm injuries were 2.3 times (95% CI: 2.1-2.5) (excluded ISS=75) or 2.2 times (95% CI: 1.9-2.3) (excluded self-inflicted injuries) more likely than cut/pierce injuries to require ICU admission (main analysis RR= 2.3). When excluding injuries with ISS equal to 75 or self-inflicted injuries, firearm injuries were associated with higher ISS scores in all injury subcohorts compared to cut/pierce injuries. Similar patterns were found in hospital and ICU LOS, with cut/pierce injuries more likely to have short hospital and ICU LOS and firearm injuries more likely to have prolonged hospital and ICU LOS (**eTable 1 and eTable 2)**. Sensitivity analysis for LOS demonstrated similar results to primary analysis. Firearm injuries were associated with more days of hospitalization compared to cut/pierce injuries for all injuries and non-critical firearm injurie. Critical firearm injuries were associated with more days of hospitalization and more days of ICU stay compared to critical cut/pierce injuries **(eTable 3)**.

Discussion

We have limited knowledge of short-term clinical outcomes and resource utilization in pediatric patients who sustain a firearm injury. This study expands upon that evidence and is one of the first, to our knowledge, to contextualize pediatric firearm injuries in the broader scope of pediatric penetrating sharp force injuries at the national level. These findings indicate a notable distinction for firearm. In addition to their previously known high case-fatality, these findings indicate a high burden of injury severity and resource utilization associated with firearm injuries including among the cohort of critically-injured children.[10,14,19]

In our comparison based on means, firearm injuries were associated with an almost 7 point higher ISS score compared to cut/pierce injuries. The mean ISS for firearm injuries was greater than twice that of cut/pierce injuries (10.2 and 4.6, respectively). Among critical injuries, the mean ISS for firearms was over 50% greater in firearm injuries compared to cut/pierce injuries (17.2 and 11.0, respectively). These additive severity points associated with firearm injury reflect an important clinical distinction be\tween firearm injuries and cut/pierce injuries. Mean ISS score for cut/pierce injuries is categorized as mild (ISS <9) compared to moderate for firearm injuries (ISS 9-15). In critical injuries, mean ISS score for cut/pierce injuries is categorized as moderate compared to severe for firearm injuries (ISS >15). This higher injury severity category associated with the additive ISS points associated with firearm injury represents a notable increased risk of morbidity and mortality. This distinction is maintained even when examining the cohort of critically-injured children in isolation. This highlights the clinical distinction between firearm injuries and cut/pierce injuries across the spectrum of gravity of injury.

Additionally, we demonstrated that compared to children injured with cut/pierce injuries, those who sustain a firearm injury were more than twice as likely to be critically injured and require ICU admission. Children injured by firearms were more likely to have longer hospital LOS. Despite similar numbers of patient encounters for firearm injuries and cut/pierce injuries, firearm injuries resulted in nearly 2-fold greater hospital days and nearly 5-fold greater ICU days. These markers of shorter and longer-term outcomes are important as ICU admission and longer LOS are associated with increased risk for morbidity and complications and reflect a high economic burden and resource utilization.

High velocity and impact bullets carry significant force that is higher than many tools that can cause cut/pierce injury. When the bullet transfers force to a human body upon impact, it results in significant damage to local and surrounding structures. A Bullet, for example, can easily cause injuries to structures such as the brain when a knife would be unable to penetrate the skull.

Similarly, bullets can be fired in rapid succession, and therefore a child can sustain multiple injuries to different areas of the body. With greater local damage and more injury locations, there is increased likelihood of injury to a vital area, such as a vascular structure, a nerve, or hollow viscous resulting in the need for an operative intervention. Although we did not examine number of procedures performed, this could also explain the longer ICU and hospital LOS in firearm injuries if these patients required more operative interventions as a result of their injury. As ISS score takes into account various injury locations and sums them into a full score, injury to multiple areas of the body could account for higher ISS scores in children injured by firearms compared to children injured by non-firearm penetrating trauma mechanisms.

We considered two additional explanations for the higher severity markers associated with firearm injuries: higher mortality in firearm injuries and self-inflicted firearm injuries which often take the form of gunshot wounds to the head. We therefore performed a sensitivity analysis to assess this possibility. We found no difference in our primary conclusions when excluding patients who had self-inflicted injures or when excluding patients with ISS equal to 75 consistent with a unsurvivable injury. Firearm injuries were still associated with higher ISS points, higher likelihood of ICU admission, and higher likelihood of long hospital and ICU LOS. These findings confirm that injury severity in firearm injuries compared to cut/pierce injuries is not driven solely by fatalities or self-inflicted injuries. This strengthens our conclusions about the distinct injury burden inflicted by firearms.

Previous studies have documented ISS scores and ICU admission percentage in children who sustain a firearm injury.[5,6,8,13,16,17,20,26,29] Comparison of ICU percentages and ISS scores is difficult between studies, as different databases capture different cohorts of children and many previous studies were single center studies. This study adds a greater understanding of the distinctness of firearm injuries among the greater group of pediatric trauma injuries through a comparison with cut/pierce injuries.

There are limitations to our study. First, although the NTDB represents the largest collection of trauma data, the population of firearm injuries and cut/pierce injuries is not fully comprehensive and does not capture every pediatric firearm or cut/pierce injury over the 10-year time period. Injuries that are not captured by the NTDB include those injuries that result in death at the scene of injury. This is more likely to occur in firearm injuries and result in a subset of fatal firearm injuries excluded from this study. Additionally, the NTDB is a collection of encounter level data. As a result, it is not possible to link encounters by patient or determine

which patients had repeat injuries during the data period. In order to address this issue, we eliminated all encounters that were coded as "transferred" to eliminate the double counting of injuries. This ultimately likely removed a subset of pediatric patients who were critically injured and transferred to a hospital with expertise in pediatric trauma, as information was then only available from their initial hospitalization. This likely affected firearm injuries and cut/pierce injuries similarly and may have resulted in a small decrease in the sample size and power of the study. Another limitation inherent in the use of the NTDB is the lack of longitudinal follow up data as well as cost or monetary measures, which are not collected.

Future research directions should focus on possible explanations for the increased severity of pediatric firearm injuries compared to cut/pierce injuries, examine data on procedure, complications, and disposition for injury encounters, and focus on those with ongoing morbidity. Further studies should also focus on most recent years of data once those become available to capture the changing epidemiology of pediatric firearm injuries, especially the recent increases in the rates of suicide attempts via firearms.

Conclusions

This study highlights the distinct severity and resource utilization associated with pediatric firearm injuries compared to other penetrating sharp force injuries, including among critical injuries. This raises the important consideration of means. Firearms pose a notably high morbidity risk and should be treated with unique caution. Efforts to reduce pediatric firearm injuries through legislative efforts, safe storage practices, and community-based interventions are vital to the safety of our nation's children.

Table 1. Demographic characteristics of patients for all injuries and critical injuries

	All Injuries			Critical Injuries		
	Firearm (n=25155)	**Cut/Pierce** (n=21270)	**Total** (n=46425)	**Firearm** (n=7682)	**Cut/Pierce** (n=2712)	**Total** (n=10394)
Age						
0-4 years	1144 (4.55)	2912 (13.69)	4056 (8.74)	373 (4.86)	298 (10.99)	671 (6.46)
5-9 years	1028 (4.09)	2888 (13.58)	3916 (8.44)	299 (3.89)	217 (8.00)	516 (4.96)
10-14 years	4176 (16.60)	4575 (21.51)	8751 (18.85)	1285 (16.73)	448 (16.52)	1733 (16.67)
15-17 years	18807 (74.76)	10895 (51.22)	29702 (63.98)	5725 (74.52)	1749 (64.49)	7474 (71.91)
Sex						
Male	21573 (85.76)	15864 (74.58)	37437 (80.64)	6581 (85.67)	2183 (80.49)	8764 (84.32)
Female	3582 (14.24)	5406 (25.42)	8988 (19.36)	1101 (14.33)	529 (19.51)	1630 (15.68)
Race						
White	3983 (16.25)	7977 (38.83)	11960 (26.55)	1422 (19.02)	857 (32.73)	2279 (22.58)
African- American	15019 (61.27)	6397 (31.14)	21416 (47.53)	4257 (56.94)	748 (28.57)	5005 (49.58)
Hispanic	4322 (17.63)	4643 (22.60)	8965 (19.90)	1444 (19.32)	777 (29.68)	2221 (22.00)
Other	1187 (4.84)	1527 (7.43)	2714 (6.02)	353 (4.72)	236 (9.01)	589 (5.84)
Insurance						
Private	5583 (27.94)	6473 (36.75)	12056 (32.07)	1892 (30.77)	819 (37.23)	2711 (32.47)
Medicaid	10775 (53.93)	8762 (49.74)	19537 (51.97)	3487 (56.71)	1112 (50.55)	4599 (55.08)
Self Pay	3621 (18.12)	2380 (13.51)	6001 (15.96)	770 (12.52)	269 (12.23)	1039 (12.44)
Intent						
Assault	19057 (79.90)	8543 (40.59)	27600 (61.47)	5684 (77.91)	1715 (63.71)	7399 (74.08)
Self-Inflicted	1189 (4.98)	1875 (8.91)	3064 (6.82)	607 (8.32)	227 (8.43)	834 (8.35)
Unintentional	3606 (15.12)	10629 (50.50)	14235 (31.70)	1005 (13.77)	750 (27.86)	1755 (17.57)

Numbers in cells represent frequencies and (percentages)

Table 2. Clinical characteristics of all injuries and critical injuries

	Firearm	**Cut/Pierce**	**Total**
All Injuries			
Injury Severity Score[a]	10.94 (1-16)	4.59 (1-5)	8.03 (1-10)
Hospital Length of Stay[a]	5.01 (1-6)	2.76 (1-3)	3.98 (1-4)
ICU admission[b]	7682 (30.54)	2712 (12.75)	10394 (22.39)
Critical Injuries			
Injury Severity Score[a]	17.23 (9-25)	10.96 (4-14)	15.58 (9-25)
Hospital Length of Stay[a]	10.38 (3-13)	6.50 (2-7)	9.37 (3-11)
ICU Length of Stay[a]	5.11 (1-5)	3.08 (1-3)	4.58 (1-5)
Ventilator[b]	3409 (44.38)	699 (25.77)	4108 (39.52)
Ventilator Days[a]	4.96 (1-5)	3.19 (1-3)	4.66 (1-5)

[a]Mean and (interquartile range)
[b]Frequencies and (percentages)

Figure 1. Adjusted additive higher injury severity score associated with firearm injuries than cut/pierce injuries

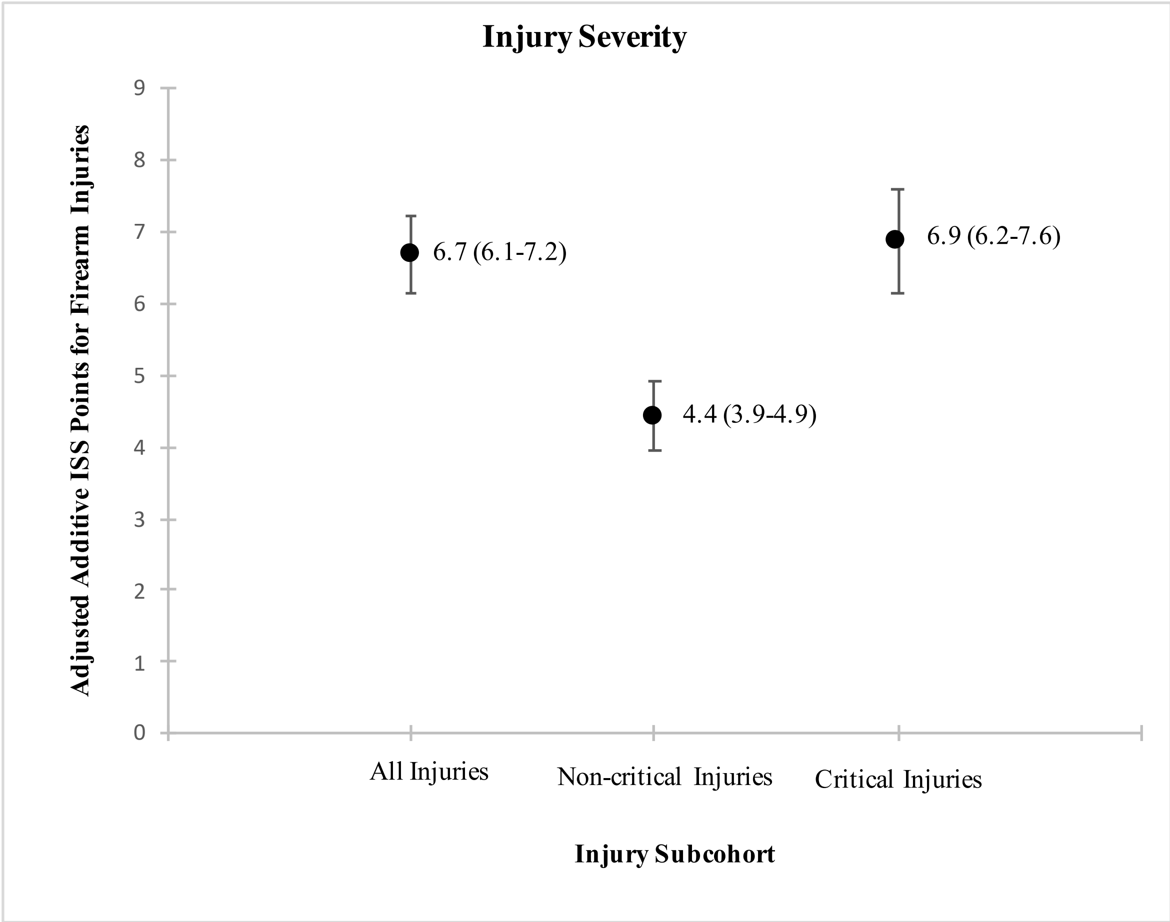
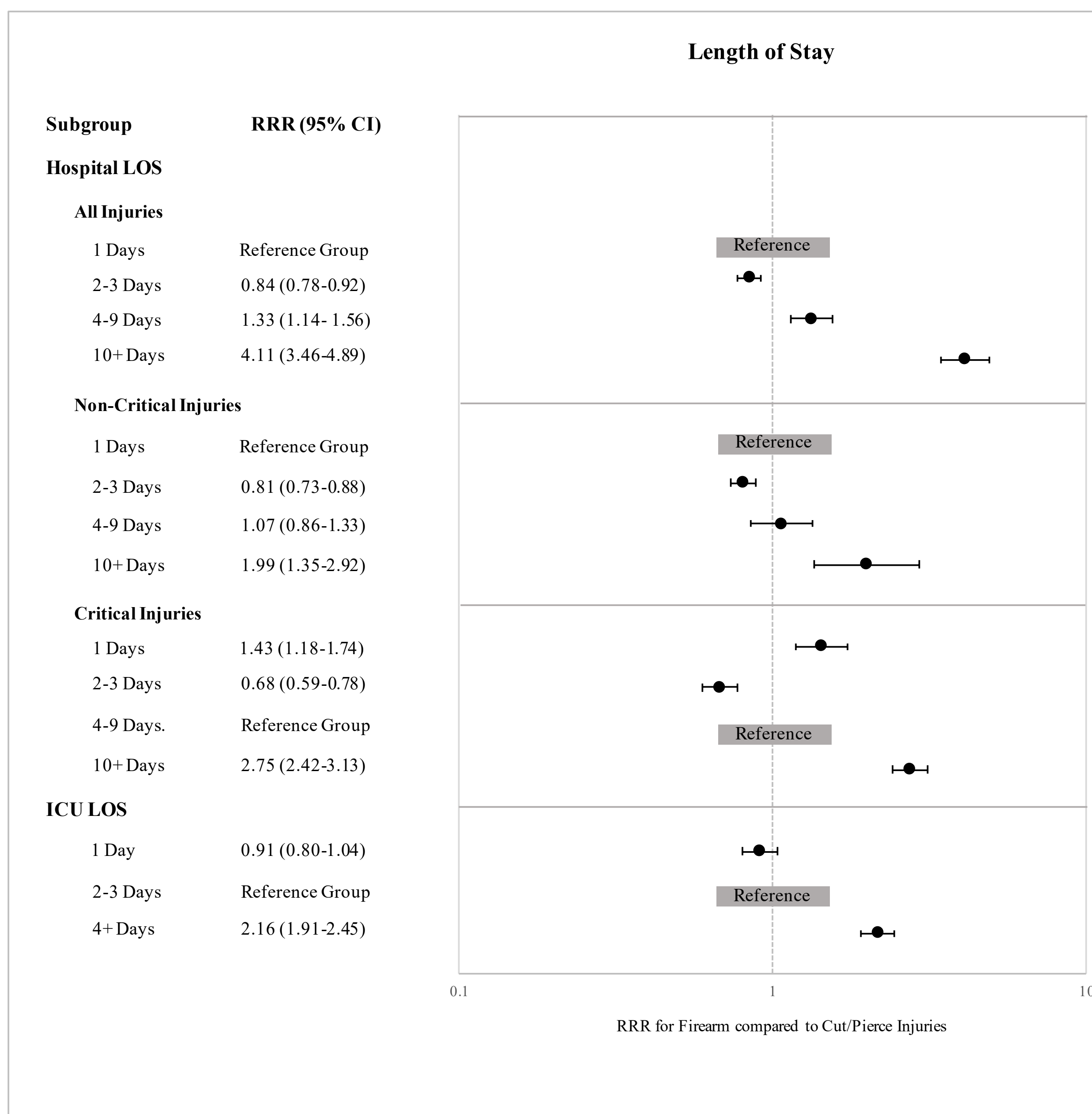


Figure 2. Hospital and ICU length of stay relative risk ratios for firearm injuries compared to cut/pierce injuries



RRR for firearm compared

eTable 1.

Sensitivity analysis excluding ISS equal to 75 summary of results

Outcome	Estimate (95%CI)
ICU Admission	RR 2.30 (2.07-2.54)
ISS	
All Injuries	Additive Points 5.69 (5.26-6.13)
Non-Critical Injuries	Additive Points 3.29 (2.95-3.63)
Critical Injuries	Additive Points 6.78 (6.15-7.40)

Hospital LOS	
All Injuries	
2-3 Days	RRR 0.86 (0.79-0.94)
4-9 Days	RRR 1.37 (1.17-1.61)
10+ Days	RRR 4.22 (3.54-5.03)
Non-Critical Injuries	
2-3 Days	RRR 0.83 (0.75-0.91)
4-9 Days	RRR 1.10 (0.88-1.37)
10+ Days	RRR 2.04 (1.38-3.00)
Critical Injuries	
1 Days	RRR 1.38 (1.14-1.68)
2-3 Days	RRR 0.67 (0.58-0.76)
10+ Days	RRR 2.74 (2.40-3.12)
ICU LOS	
1 Day	RRR 0.90 (0.79-1.03)
4+ Days	RRR 2.18 (1.92-2.46.)

eTable 2.

Sensitivity analysis excluding self-inflicted injuries summary of results

Outcome	**Estimate (95%CI)**
ICU Admission	RR 2.19 (2.01-2.39)
ISS	
All Injuries	Additive Points 6.01 (5.58- 6.44)
Non-Critical Injuries	Additive Points 4.07 (3.62-4.52)
Critical Injuries	Additive Points 5.75 (5.05-6.46)
Hospital LOS	
All Injuries	
2-3 Days	RRR 0.88 (0.81- 0.96)
4-9 Days	RRR 1.50 (1.38-1.64)
10+ Days	RRR 4.60 (4.11- 5.16)
Non-Critical Injuries	
2-3 Days	RRR 0.84 (0.77-0.92)
4-9 Days	RRR 1.25 (1.13-1.38)
10+ Days	RRR 2.62 (2.23- 3.07)
Critical Injuries	
1 Days	RRR 1.22 (1.00-1.50)
2-3 Days	RRR 0.67 (0.58-0.77)
10+ Days	RRR 2.71 (2.37-3.10)
ICU LOS	
1 Day	RRR 0.89 (0.78-1.02)
4+ Days	RRR 2.16 (1.89- 2.47)

eTable 3.

Sensitivity analysis using Poisson model for hospital and ICU LOS summary of results

Outcome	**Estimate (95% CI)**
Hospital LOS	
All Injuries	IRR 1.77 (1.66-1.89)
Non-Critical Injuries	IRR 1.16 (1.06-1.28)

Critical Injuries	IRR 1.61 (1.52-1.71)
ICU LOS	IRR 1.69 (1.57-1.82)

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