# Firearm-Related Hospitalization and Risk for Subsequent Violent Injury, Death, or Crime Perpetration
## A Cohort Study

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**Background:** Risk for violent victimization or crime perpetration after firearm-related hospitalization (FRH) must be determined to inform the need for future interventions.

**Objective:** To compare the risk for subsequent violent injury, death, or crime perpetration among patients with an FRH, those hospitalized for noninjury reasons, and the general population.

**Design:** Retrospective cohort study.

**Setting:** All hospitals in Washington.

**Patients:** Patients with an FRH and a random sample of those with a non–injury-related hospitalization in 2006 to 2007 (index hospitalization).

**Measurements:** Primary outcomes included subsequent FRH, firearm-related death, and the combined outcome of firearm- or violence-related arrest ascertained through 2011.

**Results:** Among patients with an index FRH (n = 613), rates of subsequent FRH, firearm-related death, and firearm- or violence-related arrest were 329 (95% CI, 142 to 649), 100 (CI, 21 to 293), and 4221 (CI, 3352 to 5246) per 100 000 person-years, respectively. Compared with the general population, standardized incidence ratios among patients with an index FRH were 30.1 (CI, 14.9 to 61.0) for a subsequent FRH and 7.3 (CI, 2.4 to 22.9) for firearm-related death. In survival analyses that accounted for competing risks, patients with an index FRH were at greater risk for subsequent FRH (subhazard ratio [sHR], 21.2 [CI, 7.0 to 64.0]), firearm-related death (sHR, 4.3 [CI, 1.3 to 14.1]), and firearm- or violence-related arrest (sHR, 2.7 [CI, 2.0 to 3.5]) than those with a non–injury-related index hospitalization.

**Limitation:** Lack of information on whether patients continued to reside in Washington during follow-up may have introduced outcome misclassification.

**Conclusion:** Hospitalization for a firearm-related injury is associated with a heightened risk for subsequent violent victimization or crime perpetration. Further research at the intersection of clinical care, the criminal justice system, and public health to evaluate the effectiveness of interventions delivered to survivors of firearm-related injury is warranted.

Seventy percent of homicides and 10% of nonfatal violent crimes in the United States are related to firearms (1–3). There are 40 times as many nonfatal firearm-related crimes as there are firearm-related deaths, and 23% of victims of such crimes sustain an injury (3). Of those with nonfatal firearm-related injuries that receive medical attention in the emergency department, an estimated 30% to 60% are hospitalized, depending on the injury intent (4). Overall, firearm-related hospitalizations (FRHs) are associated with substantial physical and psychological morbidity as well as societal cost (5–7).

Information on the risk for subsequent violent victimization (that is, becoming a victim) or crime perpetration after an FRH is lacking. Such information must be obtained to inform the need for future interventions among this group of patients. For example, interventions, such as brief motivational interviewing, conducted among trauma patients during their hospitalization have been shown to reduce rates of posttraumatic stress and alcohol use disorders as well as trauma and violent behavior recidivism while improving functional recovery (8–10). An enhanced understanding of the subsequent risk for violent injury, death, or crime perpetration may help frontline health care providers, public health professionals, criminal justice officials, and policymakers devise and implement integrated risk assessment plans and harm reduction strategies at the time of hospitalization and after discharge among patients with an FRH.

We conducted a statewide epidemiologic investigation to determine the absolute rates of subsequent violent injury, death, or crime perpetration after discharge among patients with an FRH, and to compare these rates with those of 2 comparison groups comprising patients hospitalized for noninjury reasons and the general population. Our hypothesis was that patients with an FRH were at highest risk for violent injury, death, or crime perpetration after discharge.
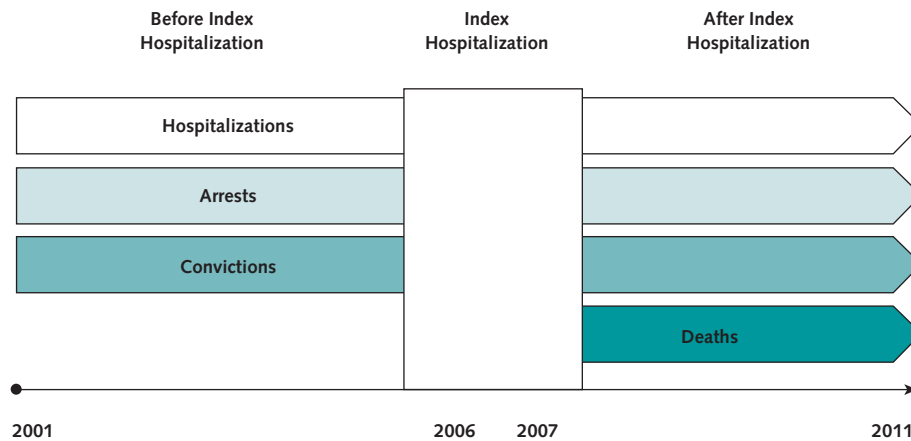
## METHODS
### Overview of Study Design
We used a retrospective cohort study design. First, using codes from the International Classification of Diseases, Ninth Revision (ICD-9), we identified all trauma patients hospitalized in 2006 to 2007 in Washington.

***Figure 1.*** Pictorial representation of study design.



Each patient's first hospitalization during these years was defined as their index hospitalization. We chose 2 comparison groups: a random sample of patients with a non–injury-related index hospitalization frequency matched with the injury group on age and year of hospitalization, and the general population of Washington. Information on outcomes was collected through 31 December 2011. The Human Subject Division of the Washington State Department of Health approved the study protocol and procedures.

### Exposures

Consistent with prior literature, an injury-related hospitalization was defined as a hospital discharge with a primary diagnosis of an acute injury (ICD-9 codes 800 to 959). Using codes for external causes of injury (E codes), we excluded records for the following mechanisms: injuries from medical and surgical misadventures (E870 to E879), late effects of injury (E929 or E999), and adverse effects of substances in therapeutic use (E930 to E949) (11).

Information on index hospitalization was obtained by using the Washington State Comprehensive Hospital Abstract Reporting System (CHARS) (12), which contains coded hospital inpatient discharge information and is used to collect an array of data elements, such as age, sex, payer status, and codes for diagnoses and procedures. Using ICD-9 and E codes, we categorized index hospitalizations into the following distinct subgroups: violent injury, which was further divided into firearm-related (of any intent [assault, self-inflicted, unintentional, or undetermined]) and non–firearm-related (assault or self-inflicted) injuries; nonviolent injury; and noninjury. We used the definition of a violent death from the National Violent Death Reporting System (NVDRS) ("an injury resulting either from the intentional use of physical force or power against oneself, another person, or a group or community" [13]) as a guide to define violent injury in this investigation. Consistent with NVDRS practice, we included firearm injuries of any intent in the subgroup of violent injury.

The primary exposure was index FRH. Secondary exposures included index hospitalization related to nonfirearm violence and hospitalization for a nonviolent injury. Index noninjury hospitalization served as the reference category.

### Outcomes

Outcomes measured after index hospitalization discharge were subsequent violence-related hospitalization, death, or arrest. Statewide records on all hospitalizations, deaths, and arrests from 2006 through 2011 were obtained from CHARS, the Washington State Department of Health, and the Washington State Patrol, respectively.

Subsequent injury-related hospitalizations and deaths were classified with the same categorization scheme used for index hospitalization. We used specific codes in the Revised Code of Washington to classify arrests as due to a firearm-related or violent crime or a nonfirearm nonviolent crime. Because the Revised Code of Washington does not typically distinguish between violent crimes that involve firearms and those that do not, we grouped firearm-related crimes (such as theft) and violent crimes (regardless of whether a firearm was involved) into 1 class ("firearm- or violence-related arrest"), as recommended by previous investigators who faced this methodological limitation (14). We used the definition of a violent crime used by the Uniform Crime Reporting program of the Federal Bureau of Investigation ("an offense that involves force or threat of force, including criminal homicide, forcible rape, robbery, and aggravated assault" [15]) as a guide to define a violent crime.

Primary outcomes included subsequent FRH, firearm-related death, and the combined outcome of firearm- or violence-related arrest. Secondary outcomes included subsequent hospitalization for a nonfirearm violent injury, nonfirearm violent death, and arrest for a nonfirearm nonviolent crime.

*Table 1.* Characteristics of the Study Population, by Type of Index Hospitalization*

| Characteristic | Violent Injury (n = 9048) | | | Nonviolent Injury (n = 68 090) | Noninjury (n = 180 841) |
| --- | --- | --- | --- | --- | --- |
| | Firearm (Any Intent) (n = 680) | Nonfirearm | | | |
| | | Assault (n = 2526) | Self-Inflicted (n = 5842) | | |
| Hospital deaths | 67 (9.9) | 65 (2.6) | 145 (2.5) | 5626 (8.3) | 4147 (2.3) |
| **Age** | | | | | |
| ≤19 y | 130 (19.1) | 414 (16.4) | 838 (14.3) | 7180 (10.5) | 13 493 (7.4) |
| 20–39 y | 374 (55.0) | 1196 (47.4) | 2574 (44.1) | 10 997 (16.2) | 27 999 (15.5) |
| 40–59 y | 129 (19.0) | 796 (31.5) | 2075 (35.5) | 15 778 (23.2) | 45 895 (25.4) |
| ≥60 y | 47 (6.9) | 120 (4.7) | 355 (6.1) | 34 135 (50.1) | 93 454 (51.7) |
| **Male†** | 584 (85.9) | 1991 (78.8) | 2293 (39.3) | 33 787 (49.6) | 71 998 (39.8) |
| **Payer status** | | | | | |
| Public | 288 (42.4) | 1266 (50.1) | 2811 (48.1) | 38 378 (56.4) | 10 2611 (56.7) |
| Private | 241 (35.4) | 739 (29.3) | 2240 (38.3) | 25 003 (36.7) | 72 502 (40.1) |
| Self | 151 (22.1) | 521 (20.6) | 791 (13.5) | 4709 (6.9) | 5728 (3.2) |
| **Discharge season‡** | | | | | |
| Winter | 155 (22.8) | 566 (22.5) | 1516 (26.4) | 16 346 (24.0) | 49 751 (27.8) |
| Spring | 185 (27.2) | 657 (26.1) | 1448 (25.3) | 16 974 (25.0) | 45 177 (25.2) |
| Summer | 163 (24.0) | 713 (28.3) | 1443 (25.2) | 18 246 (26.8) | 42 529 (23.7) |
| Fall | 177 (26.0) | 582 (23.1) | 1327 (23.1) | 16 488 (24.2) | 41 731 (23.3) |
| **County of hospital§** | | | | | |
| King | 222 (32.7) | 873 (34.5) | 1280 (21.9) | 17 814 (26.1) | 47 816 (26.5) |
| Pierce | 138 (20.3) | 406 (16.1) | 833 (14.3) | 7840 (11.5) | 21 294 (11.8) |
| Snohomish | 56 (8.2) | 171 (6.8) | 526 (9.0) | 6172 (9.1) | 17 069 (9.4) |
| Other | 264 (38.8) | 1076 (42.6) | 3203 (54.8) | 36 264 (53.3) | 94 662 (52.3) |
| **History of arrest** | | | | | |
| Firearm-related or violent crime | | | | | |
| Yes | 147 (21.6) | 548 (21.7) | 576 (9.9) | 2209 (3.2) | 2173 (1.2) |
| No | 533 (78.4) | 1978 (78.3) | 5266 (90.1) | 65 881 (96.8) | 178 668 (98.8) |
| Nonfirearm nonviolent crime | | | | | |
| Yes | 252 (37.1) | 1100 (43.5) | 1240 (21.2) | 6268 (9.2) | 6201 (3.4) |
| No | 428 (62.9) | 1426 (56.5) | 4602 (78.8) | 61 822 (90.8) | 174 640 (96.6) |
| **History of conviction** | | | | | |
| Firearm-related or violent crime | | | | | |
| Yes | 25 (3.7) | 136 (5.4) | 142 (2.4) | 531 (0.8) | 363 (0.2) |
| No | 655 (96.3) | 2390 (94.6) | 5700 (97.6) | 67 559 (99.2) | 180 478 (99.8) |
| Nonfirearm nonviolent crime | | | | | |
| Yes | 60 (8.8) | 261 (12.6) | 390 (6.7) | 1731 (2.5) | 1414 (0.8) |
| No | 620 (91.2) | 2207 (87.4) | 5452 (93.3) | 66 359 (97.5) | 179 427 (99.2) |
| **History of psychiatric disorder diagnosis** | | | | | |
| Substance use disorder | 255 (37.5) | 1348 (53.4) | 3289 (56.3) | 15 883 (23.3) | 27 732 (15.3) |
| Other psychiatric disorder | 45 (6.6) | 140 (5.5) | 1810 (31.0) | 12 145 (17.8) | 25 983 (14.4) |
| None | 380 (55.9) | 1038 (41.1) | 743 (12.7) | 40 062 (58.8) | 127 126 (70.3) |

* Data are numbers (percentages).
† Information was missing for 2 patients.
‡ Information was missing for 1805 patients.
§ Results are presented for the 3 largest counties in Washington and are collapsed for others for confidentiality reasons.

## Covariates

Information on age, sex, payer status, year and season of discharge, and county of the hospital for index hospitalization was captured. We also sought to examine the association of history of a diagnosis of psychiatric disorder, arrest, and conviction with the aforementioned outcomes. For this purpose, statewide records on all hospitalizations, arrests, and convictions from 2001 through 2005 were obtained from CHARS, the Washington State Patrol, and the Administrative Office of the Courts Judicial Information System, respectively. **Figure 1** provides a pictorial representation of the overall study design.

## Statistical Analysis

Probabilistic algorithms were used to link each patient's index hospitalization record to their hospitalization, vital status, arrest, and conviction records. A subset of identifiers, including first 2 letters of the first name, first 2 letters of the last name, date of birth, sex,

*Table 2.* Absolute Rates of Violence-Related Hospitalization, Arrest, or Death After Discharge, by Type of Index Hospitalization

| Index Hospitalization | Hospitalization | | | | | |
|---|---|---|---|---|---|---|
| | Firearm (Any Intent) | | Nonfirearm | | | |
| | | | Assault | | Self-Inflicted | |
| | Hospitalizations, n | Rate (95% CI) per 100 000 Person-Years | Hospitalizations, n | Rate (95% CI) per 100 000 Person-Years | Hospitalizations, n | Rate (95% CI) per 100 000 Person-Years |
| Violent injury (n = 8771) | | | | | | |
|   Firearm (n = 613) | 8 | 329 (142–649) | 12 | 494 (255–863) | 3 | 123 (25–361) |
|   Nonfirearm, assault (n = 2461) | 4 | 41 (11–105) | 46 | 470 (344–627) | 18 | 184 (109–291) |
|   Nonfirearm, self-inflicted (n = 5697) | 1 | 5 (0.1–28.0) | 12 | 60 (31–104) | 307 | 1529 (1363–1710) |
| Nonviolent injury (n = 62 464) | 16 | 8 (5–13) | 100 | 50 (41–61) | 195 | 98 (84–112) |
| Noninjury (n = 176 694) | 13 | 2 (1–4) | 57 | 10 (8–13) | 207 | 37 (32–42) |

* 1-sided 97.5% CI.

and first 3 digits of ZIP code of residence, was used for the linkage. The analytic database was restricted to matches with an accuracy likelihood of at least 99% (**Appendix**, available at www.annals.org).

Follow-up began on the day of index hospitalization discharge and ended on the day of the subsequent event (first hospitalization, death, or first arrest, each in its corresponding analysis) or on 31 December 2011, whichever occurred first. For the analysis of subsequent hospitalization, follow-up began 90 days after index hospitalization discharge to minimize potential misclassification of readmissions for index injury as new recurrent injury events. In a sensitivity analysis, we used a 180-day period after index hospitalization discharge. We conducted an additional sensitivity analysis in which the follow-up time for subsequent arrest began 1 day after index hospitalization discharge to minimize potential misclassification of arrests for index injury as new criminal events. We calculated the incidence rate of each outcome by type of index hospitalization. The cumulative incidence of a subsequent event for each type of index hospitalization was estimated by using the unadjusted cumulative incidence function, with death treated as a competing event for hospitalization and arrest, and other-cause mortality treated as a competing event for firearm-related mortality.

In regression analyses, we used the methods described by Fine and Gray (16) to model each outcome with the subdistribution hazards regression, with death treated as a competing event for hospitalization and arrest, and other-cause mortality treated as a competing event for firearm-related mortality. Subhazard ratios (sHRs) and their corresponding CIs were determined by using models that included variables for age, sex, payer status, county of the hospital, discharge year and season, history and type of arrest, and history and type of psychiatric disorder diagnosis. In a sensitivity analysis, history of crime was represented as a combination of arrest and conviction records (convicted, arrested but not convicted, or not arrested).

Using the age and sex distribution of the 2000 U.S. Census population, we calculated standardized incidence and mortality ratios to compare the risk for a subsequent FRH and death between patients with an

index FRH and persons in the general population of Washington. An $\alpha$ level of 0.05 was used to denote statistical significance. All tests were 2-sided and were done by using SAS, version 10 (SAS Institute), and Stata 13 (StataCorp), with the stcrreg and stcurve package for Fine and Gray (16) modeling and the dstdize package for standardization.

### Role of the Funding Source

## RESULTS

There were 77 138 index injury-related hospitalizations in 2006 to 2007. Of these, 9048 (11.7%) were due to a violent injury, including hospitalizations related to firearms (n = 680), nonfirearm assaults (n = 2526), and nonfirearm self-inflicted injuries (n = 5842). We also studied 180 841 patients with an index hospitalization that was not injury-related. Compared with patients admitted for other reasons, a greater proportion of patients with an index FRH and nonfirearm assault-related hospitalization were male and had at least 1 prior firearm- or violence-related arrest or conviction. A greater proportion of patients with a violent injury at index hospitalization had at least 1 arrest or conviction for a nonfirearm nonviolent crime and a hospitalization in which a diagnosis of psychiatric disorder was noted on any of the discharge abstract fields before their index hospitalization (**Table 1**).

In terms of the intent of the injuries sustained by patients with an FRH, 347 (51.0%) were assaults, 89 (13.1%) were self-inflicted, 192 (28.2%) were unintentional, and 52 (7.7%) were undetermined. Of 680 patients with an index FRH, 67 (9.9%) died during their hospital stay. After index hospitalization discharge, patients with an index FRH had the highest rate of subsequent FRH (329 per 100 000 person-years [95% CI, 142 to 649]) and firearm- or violence-related arrest (4221 per 100 000 person-years [CI, 3352 to 5246]) among all

*Table 2*–Continued

| | Arrest | | | Death | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Firearm-Related or Violent Crime | | Nonfirearm Nonviolent Crime | | Firearm (Any Intent) | | Nonfirearm | | | |
| | | | | | | Assault | | Self-Inflicted | |
| Arrests, n | Rate (95% CI) per 100 000 Person-Years | Arrests, n | Rate (95% CI) per 100 000 Person-Years | Deaths, n | Rate (95% CI) per 100 000 Person-Years | Deaths, n | Rate (95% CI) per 100 000 Person-Years | Deaths, n | Rate (95% CI) per 100 000 Person-Years |
| 81 | 4221 (3352–5246) | 217 | 11 307 (9853–12 917) | 3 | 100 (21–293) | 0 | 0 (0–123)* | 2 | 67 (8–242) |
| 224 | 2918 (2548–3326) | 979 | 12 753 (11 966–13 577) | 2 | 17 (2–60) | 3 | 25 (5–73) | 2 | 17 (2–60) |
| 457 | 2120 (1930–2324) | 1286 | 5966 (5644–6301) | 17 | 62 (36–100) | 3 | 11 (1–32) | 69 | 252 (196–319) |
| 1207 | 505 (477–535) | 5718 | 2394 (2332–2457) | 60 | 23 (18–30) | 9 | 3.4 (1.6–6.5) | 41 | 16 (11–21) |
| 1496 | 201 (191–211) | 5377 | 721 (702–741) | 94 | 12 (10–15) | 7 | 1 (0.4–2.0) | 95 | 12 (10–15) |

groups (Table 2). The rate of firearm-related death among patients with an index FRH was 100 per 100 000 person-years (CI, 21 to 293). The cumulative incidence of primary outcomes during follow-up by type of index hospitalization is shown in **Figure 2**, and that of other outcomes is shown in **Appendix Figures 1 to 3** (available at www.annals.org).

In adjusted analyses, patients with an index FRH were at significantly greater risk for a subsequent FRH (sHR, 21.2 [CI, 7.0 to 64.0]), firearm-related death (sHR, 4.3 [CI, 1.3 to 14.1]), and firearm- or violence-related arrest (sHR, 2.7 [CI, 2.0 to 3.5]) compared with those hospitalized for noninjury reasons (**Table 3**). In addition, patients with an index FRH were at significantly greater risk for nonfirearm assault-related hospitalization (sHR, 7.3 [CI, 3.5 to 14.9]) and nonfirearm nonviolent arrest (sHR, 1.9 [CI, 1.6 to 2.3]) than those hospitalized for noninjury reasons. Controlling for a composite of history of arrests and convictions did not materially change the results (**Appendix Table 1**, available at www.annals.org). Likewise, the 2 sensitivity analyses that included modified time at risk for ascertainment of subsequent hospitalization and arrest did not materially change the results. Patients with a history of arrest for a firearm-related or violent crime were at especially high risk for a subsequent firearm- or violence-related arrest and nonfirearm assault-related death, and those with a prior diagnosis of psychiatric disorder were at especially high risk for subsequent nonfirearm self-inflicted injury and death (**Appendix Table 2**, available at www.annals.org). Patients with an index FRH were significantly more likely than the general population of Washington to be subsequently hospitalized (standardized incidence ratio, 30.1 [CI, 14.9 to 61.0]) or die (standardized mortality ratio, 7.3 [CI, 2.4 to 22.9]) as a result of a firearm-related injury.
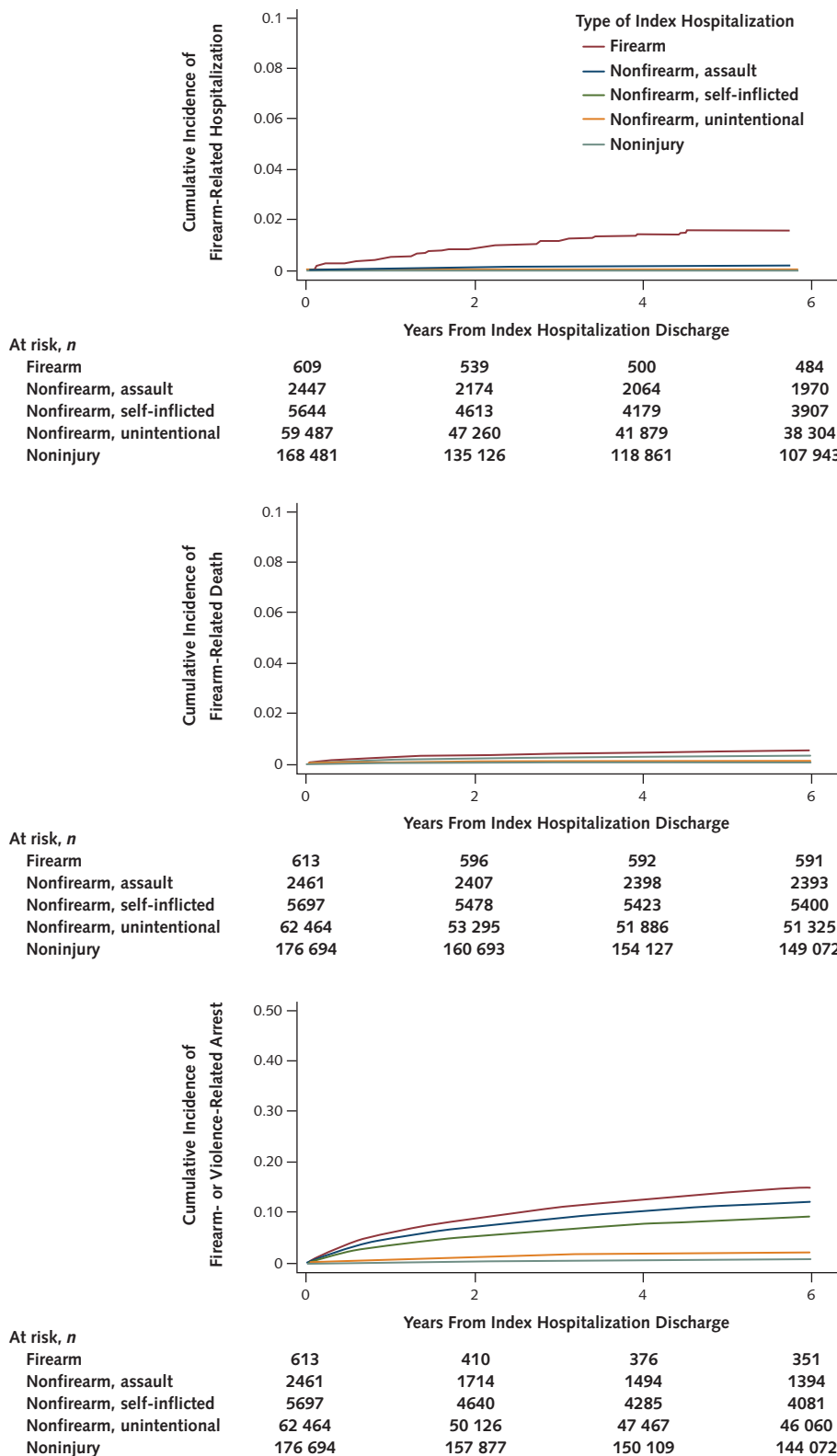
## DISCUSSION

To our knowledge, this study is one of the first comprehensive investigations of violent victimization or crime perpetration among patients with an FRH. We found that these patients were at heightened risk for subsequent firearm-related violent victimization or crime perpetration. In addition, among hospitalized patients, prior criminality had a stronger association with subsequent firearm- or violence-related arrest than did a prior diagnosis of mental illness. These findings contribute meaningfully to the existing body of literature on outcomes after an FRH and provide opportunities for further research and collaboration on developing clinical, criminal justice, and public health interventions to reduce the burden of firearm-related morbidity, mortality, and criminality.

Assault is, by a large margin, the leading cause of FRH in the United States, with almost no change in the rate of assault-related FRH in the past decade (17, 18). Consistent with prior findings, we found that 51% of all index FRHs were due to assault (18). The vast majority of patients with an FRH in this study were young men, a demographic group known to be at heightened risk for both victimization and criminal offending (19). Men represent the majority of both victims and perpetrators of firearm-related homicides (2), and about 4 to 6 times as many males as females commit suicide with a firearm in the United States (1). In our study, we observed strong associations between an index FRH and subsequent violent victimization or crime perpetration in adjusted analyses, suggesting that the heightened risk is not merely due to shared sociodemographic risk factors.

Nonfatal firearm-related injuries are associated with a high burden of morbidity and health care utilization, but their adverse consequences do not end at discharge (20, 21). Survivors of gunshot wounds have substantial short- and long-term disabilities and declines in a wide array of physical (such as functional status) and psychological (such as posttraumatic stress disorder or depression) outcomes after discharge that may in turn lead to subsequent morbidity (for example, self-inflicted injury) and mortality (5, 7, 22, 23). Trauma recurrence has been the subject of several investigations among heterogeneous populations of injured patients (11, 24–27); nonetheless, detailed information on risks for subsequent injury-related hospitalization, death, and criminal justice system involvement among persons who survive a firearm-related injury is needed. We found that patients with an index FRH were not only

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*Figure 2.* Cumulative incidence of primary outcomes after index hospitalization discharge.



Top. Firearm-related hospitalization. Middle. Firearm-related death. Bottom. Firearm- or violence-related arrest.

*Table 3.* sHRs of Violence-Related Hospitalization, Arrest, or Death After Discharge, by Type of Index Hospitalization*

| Index Hospitalization | Hospitalization | | | Arrest | | Death | | |
|---|---|---|---|---|---|---|---|---|
| | Firearm (Any Intent) | Nonfirearm | | Firearm-Related or Violent Crime | Nonfirearm Nonviolent Crime | Firearm (Any Intent) | Nonfirearm | |
| | | Assault | Self-Inflicted | | | | Assault | Self-Inflicted |
| Violent injury (n = 8655) | | | | | | | | |
| Firearm (n = 613) | 21.2 (7.0–64.0) | 7.3 (3.5–14.9) | 1.7 (0.5–5.3) | 2.7 (2.0–3.5) | 1.9 (1.6–2.3) | 4.3 (1.3–14.1) | 0 (0–NE) | 3.0 (0.7–12.6) |
| Nonfirearm, assault (n = 2453) | 3.1 (0.9–10.3) | 6.6 (4.0–10.7) | 2.1 (1.3–3.5) | 2.0 (1.7–2.4) | 2.0 (1.9–2.2) | 0.7 (0.2–2.7) | 4.6 (0.8–25.8) | 0.7 (0.2–2.9) |
| Nonfirearm, self-inflicted (n = 5589) | 0.8 (0.1–5.8) | 1.6 (0.8–3.3) | 11.9 (9.5–14.8) | 2.4 (2.1–2.8) | 1.7 (1.6–1.8) | 4.1 (2.3–7.3) | 5.5 (1.1–27.8) | 10.6 (6.8–16.6) |
| Nonviolent injury (n = 62 428) | 1.7 (0.8–3.8) | 2.5 (1.7–3.5) | 2.1 (1.7–2.6) | 1.4 (1.3–1.6) | 1.6 (1.5–1.6) | 1.4 (1.0–1.9) | 2.3 (0.8–7.0) | 1.0 (0.7–1.4) |
| Noninjury (n = 175 039) | 1.0 (Reference) | 1.0 (Reference) | 1.0 (Reference) | 1.0 (Reference) | 1.0 (Reference) | 1.0 (Reference) | 1.0 (Reference) | 1.0 (Reference) |

NE = not estimated; sHR = subhazard ratio.
* Values are sHRs (95% CIs), which were determined by using models that also included age, sex, payer status, discharge year and season, county of the hospital, history of diagnosis of psychiatric disorder, and history of arrest. A total of 1807 patients with missing data on sex or discharge season were excluded from these analyses.

substantially more likely to experience a subsequent firearm-related event, they were also more likely to be subsequently hospitalized for a nonfirearm assault-related injury or arrested for a nonfirearm nonviolent crime than those whose index hospitalization was not injury-related.

A contribution of this study is to highlight the characteristics of a subset of persons who come into contact with the health care system and are most likely to return with violent injuries, die from those injuries, or be arrested for perpetrating violent crimes. Specifically, patients with prior criminality had a high likelihood of being murdered within 5 years after their index hospitalization. The natural history of criminal careers, potential for recidivism, and risk factors for criminal offending and victimization are well-described in the criminology literature (28–34). In particular, many prior investigations conducted outside the inpatient setting have documented the link between prior criminality and risk for subsequent crime among persons who own or use guns. For example, Wintemute and colleagues (14) found that male handgun purchasers with prior convictions for a violent misdemeanor were more than 10 times as likely as those with no such history to be subsequently charged with a firearm-related or violent crime. In our investigation, prior criminality had a stronger association with subsequent firearm- or violence-related arrest than did a prior diagnosis of mental illness. Findings of previous investigations have suggested that certain psychiatric illnesses, particularly substance use disorders, are associated with an increased risk for trauma and violent behavior (24, 35, 36). Nonetheless, the relationship between mental illness and violent behavior is complex; the vast majority of persons with mental illness do not engage in violent behavior. Several investigators have challenged the general perception of mental illness as one of the leading causes of violent behavior by emphasizing the need to take other factors into account, such as a history of violent behavior or societal and environmental stressors associated with mental illness (37–39).

The primary limitations of this study pertain to the use of existing records that did not include all potentially useful information. First, CHARS data for the index years in this investigation did not include information on race. Prior commentary suggests that among explanatory predictors of crime, the most salient are environmental and socioeconomic factors rather than individual characteristics, such as race, and that the burden of FRHs and death is substantially greater among disadvantaged groups (28, 40, 41). We attempted to partially overcome this limitation by controlling for payer status and county of hospital in our analyses. Second, because of the nature of the databases we used, we did not know whether patients continued to reside in Washington after their index hospitalization discharge; therefore, rates of subsequent hospitalization, death, and arrest have likely been underestimated. Residential mobility is associated with poverty and crime (42); therefore, outcome rates may have been particularly underestimated among persons with prior criminality in this investigation. Third, the probabilistic linkage of records may have missed true matches or erroneously created false ones; however, we restricted the analytic database to matches with a high likelihood of accuracy to minimize concerns about misclassification. Fourth, the determination of psychiatric disorder was based on chart diagnosis using ICD-9 codes rather than chart review. It is possible that a fraction of patients with mental illness did not receive a

diagnosis of psychiatric disorder in the hospital setting; therefore, our findings should not be interpreted as pertaining to all persons with mental illness. Likewise, subsequent violent victimization was measured using hospitalization and death records and did not include incidents that had not resulted in an inpatient medical encounter or death. Patients who sustained a firearm-related injury with no hospitalization records or those who committed a crime that did not result in an arrest did not contribute information to events of interest in the analyses. Finally, selection bias may have been introduced because one basis for comparison was other hospitalized patients whose propensity for subsequent injury, death, or crime perpetration may not be representative of that in the underlying population. As such, we also compared the rates of injury and death among patients with an FRH and persons in the general population of Washington to provide another basis for comparison.

This investigation builds and expands on the existing body of knowledge by providing evidence on the connection between firearm-related injury and subsequent violent victimization or crime perpetration among hospitalized patients. One avenue for further research is to operationalize a collaborative intervention, considering that FRH can potentially play an important role in identifying and reaching high-risk persons. Those already involved in a cycle of violence who have a medical encounter may benefit from interventions to change a trajectory that would otherwise result in subsequent violent injury, death, or crime perpetration. Secondary and tertiary prevention measures may begin in the outpatient, emergency department, or inpatient setting and continue afterward in conjunction with community services and assistance from law enforcement to offer counseling on avoiding repeated injury and new criminal activity (43–45). These interventions should ideally be multicomponent and address pathophysiologic, behavioral, and social determinants of morbidity and mortality among this group of patients (46).

In conclusion, findings of this study indicate that hospitalization for a firearm-related injury is associated with a heightened risk for subsequent violent victimization or crime perpetration. Among hospitalized patients, prior criminality has a stronger association with subsequent violent crime perpetration than a prior diagnosis of mental illness. Further research at the intersection of clinical care, the criminal justice system, and public health to design and evaluate the feasibility and effectiveness of interventions delivered to survivors of firearm-related injury is warranted.

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## APPENDIX: DATA LINKAGE PROCESS

The focus in building an analytic data set for this project was to identify records of patients hospitalized with an injury in 2006 to 2007 in CHARS along with a comparison group of noninjury admissions in those years (index hospitalization). Subsequently, patients' index hospitalization record was linked to their prior and subsequent hospitalization records in CHARS databases, arrest records in Washington State Patrol (WSP) databases, and conviction records in Washington State Administrative Office of the Courts (AOC) databases. Death records in Washington State Vital Records databases were also linked.

The project included many linkages, the first and most necessary of which involved creating a Washington State Longitudinal Hospital Admissions (WSLHA) data set, which identified and linked all potential admissions per patient in CHARS. The first approach was a deterministic linkage in which values in variables between the 2 tables were compared and a hierarchical "match" value was created. A common term for linkage procedure is "blocking," whereby specific variables are required to match exactly, and then other variables which may not be exactly equal are compared. The resulting "match" variable had values such as the following for eventual linked records:

1 – Last Name (LN) + First Name (FN) + Date of Birth (DOB) + Sex + ZIP

2 – Last Name (LN) + First Name (FN) + Date of Birth (DOB) + Sex (missing) + ZIP

So, for "match = 1", all variables matched exactly. This is as good as it gets. For "match = 2", sex was missing, but all other variables matched exactly. Along with the main "match" variable, other separate variables were created, such as "lmat" for Last Name. A "soundex" code was created for name variables, so that:

lmat =

1 – Exact Last Name

2 – Soundex + Last Name

3 – Last Name contains Last Name (i.e. SMITH-JONES to JONES)

4 – One character off (i.e., Connell to Conell)

5 – . . .

For these, the "match" variable might have a value such as:

21 – Last Name (lmat = 3) + First Name + DOB + sex + ZIP

Once blocking for one variable was complete, blocking on another variable was used to look at differences with the first linkage variable. This hierarchical technique continued such that in some linkages the values in "match" were in the hundreds. Along with the deterministic linkages described earlier, probabilistic linkages were implemented. Variables, such as Last Name (LN_per), First Name (FN_per), and ZIP (ZP_per), were created based on the percentage of each value as a whole (that is, 200 000 records; Last Name = Jones 1000 times; LN_per = 0.05). These new variables were then used to confirm linkages that may otherwise have been ignored. The hierarchy was used to make a determination on the threshold for excluding records. In this investigation, we excluded records with less than 99% probability of a true match.

CHARS data before 2009 had limited identifiers, primarily LN, FN, DOB, sex, and ZIP code of residence (that is, block of LNFN + DOB + Sex + ZIP). In 2009, the addition of full names and a partial social security number (SSN) greatly enhanced the linkage results. WSLHA was created in 2 steps. The first step included linkage of all CHARS records for 1987 to 2012 using the limited identifiers available. The second involved linkage only for CHARS records where the full names and SSNs were available. Considering the limited population of Washington, an exact match of the linkage variables created a highly secure final result (beta_2). The criteria and results from "beta_1" were then compared to that of "beta_2". Linkages from "beta_1" that were determined to be insufficient for "beta_2" were excluded from "beta_1" along with all other records from "beta_1" with

the same matching criteria as those exclusions. The remaining "beta_1" and "beta_2" files were then united to create WSLHA. This dual step process was repeated later for death, WSP, and AOC linkages.
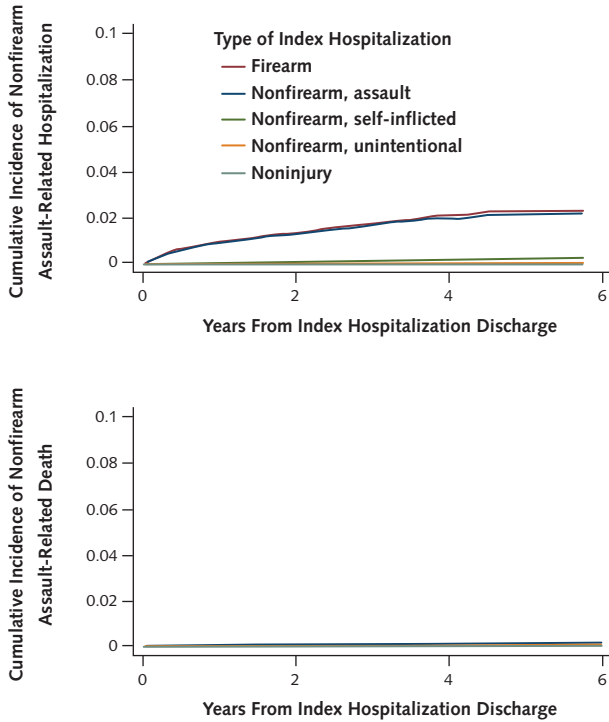
Admissions in 2006 to 2007 in CHARS for patients with an injury identified by the ICD-9 E Code formed index hospitalization records of the injury group. Similarly, a comparison group without an injury code frequency matched to the injury group by age in 5-year categories and year of admission was created. The 2 aforementioned data sets created the original working data set (mast1). WSLHA was used to identify only 1 admission per patient and to ensure that the comparison group did not include secondary admissions of the injury group. All prior and subsequent admissions to records in "mast1" were then identified to create "mast2", again using WSLHA. The last admission per patient was identified using "mast2" for those with a subsequent admission after "mast1", and using "mast1" when no subsequent admission was found. This process created "mast3", which was then linked to death records by using all available identifying variables. The linkage to death records was robust; some of the later admissions included full names, and some others identified the discharge status as a death; so, the addition of death dates to CHARS dates greatly enhanced the linkage.
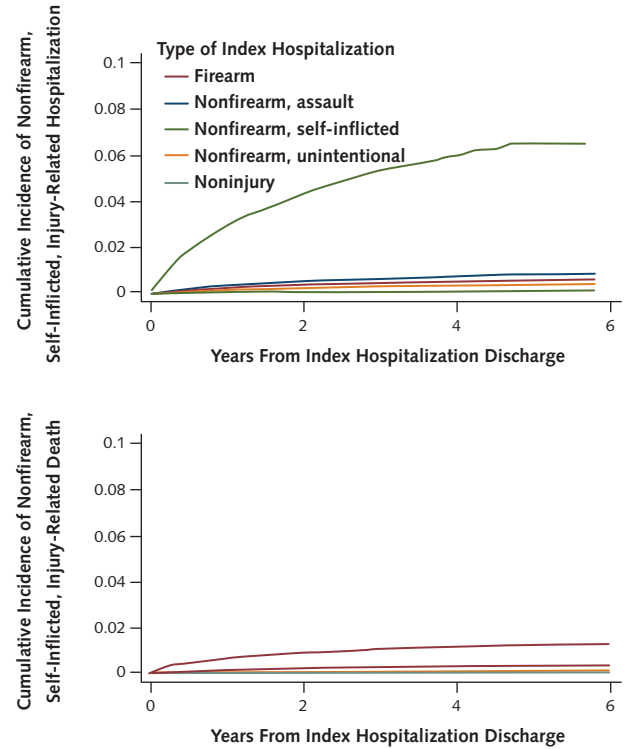
One data set for WSP and another for AOC records with all pertinent variables was prepared and linked to CHARS (mast1) variables using the same linkage variables as previously mentioned. Once the WSP and AOC data sets were linked, the dual-step process described earlier with WSLHA was repeated on the linkages. Eventually all linkages were combined with "mast1" and a subsequent final "master" data set was created, including other CHARS admissions from "mast2". In all linkages, more weight was given to less common LNFN and less common ZIP codes in the probabilistic hierarchy.

Link Plus, a probabilistic record linkage program developed at the Centers for Disease Control and Prevention, was used and results were compared against those obtained from programming in FoxPro (Microsoft) to improve the linkage process. One data programmer performed all data linkages. No protected health information was sent to the analysis team. To allow analysis based on the exact time of events, variables were created to identify the number of days between events, eliminating the need for specific dates entirely.

*Appendix Figure 1.* Cumulative incidence of nonfirearm assault-related hospitalization (*top*) and nonfirearm assault-related death (*bottom*) after index hospitalization discharge.



*Appendix Figure 2.* Cumulative incidence of nonfirearm, self-inflicted, injury-related hospitalization (*top*) and nonfirearm, self-inflicted, injury-related death (*bottom*) after index hospitalization discharge.



*Appendix Figure 3.* Cumulative incidence of nonfirearm nonviolent arrest after index hospitalization discharge.

*Appendix Table 1.* sHRs of Violence-Related Hospitalization, Arrest, or Death After Discharge, by Type of Index Hospitalization and Controlled for History of Arrest and Conviction*

| Index Hospitalization | Hospitalization | | | Arrest | | | Death | |
|---|---|---|---|---|---|---|---|---|
| | Firearm (Any Intent) | Nonfirearm | | Firearm-Related or Violent Crime | Nonfirearm Nonviolent Crime | Firearm (Any Intent) | Nonfirearm | |
| | | Assault | Self-Inflicted | | | | Assault | Self-Inflicted |
| **Violent injury (n = 8655)** | | | | | | | | |
| Firearm (n = 613) | 20.5 (6.8–61.9) | 7.1 (3.5–14.6) | 1.7 (0.5–5.3) | 2.6 (1.9–3.4) | 1.9 (1.5–2.2) | 4.2 (1.3–13.7) | 0 (0–NE) | 3.1 (0.7–13.1) |
| Nonfirearm, assault (n = 2453) | 3.0 (0.9–10.0) | 6.4 (3.9–10.4) | 2.1 (1.3–3.5) | 2.0 (1.7–2.3) | 2.0 (1.8–2.2) | 0.7 (0.2–2.6) | 4.3 (0.8–24.0) | 0.7 (0.2–2.8) |
| Nonfirearm, self-inflicted (n = 5589) | 0.7 (0.1–5.8) | 1.6 (0.8–3.2) | 11.8 (9.4–14.7) | 2.4 (2.1–2.7) | 1.7 (1.5–1.9) | 4.0 (2.2–7.2) | 5.4 (1.1–26.7) | 10.4 (6.7–16.4) |
| Nonviolent injury (n = 62 428) | 1.7 (0.8–3.7) | 2.4 (1.7–3.5) | 2.1 (1.7–2.5) | 1.4 (1.3–1.5) | 1.5 (1.4–1.6) | 1.4 (1.0–1.9) | 2.3 (0.7–6.9) | 0.9 (0.6–1.4) |
| Noninjury (n = 175 039) | 1.0 (Reference) | 1.0 (Reference) | 1.0 (Reference) | 1.0 (Reference) | 1.0 (Reference) | 1.0 (Reference) | 1.0 (Reference) | 1.0 (Reference) |

NE = not estimated; sHR = subhazard ratio.
* Values are sHRs (95% CIs), which were determined by using models that also included age, sex, payer status, discharge year and season, county of the hospital, history of diagnosis of psychiatric disorder, and history of arrest and conviction. A total of 1807 patients with missing data on sex or discharge season were excluded from these analyses.

*Appendix Table 2.* sHRs of Violence-Related Hospitalization, Arrest, or Death After Discharge, by History and Type of Arrest and Psychiatric Disorder Diagnosis*

| Variable | Hospitalization | | | Arrest | | | Death | |
|---|---|---|---|---|---|---|---|---|
| | Firearm (Any Intent) | Nonfirearm | | Firearm-Related or Violent Crime | Nonfirearm Nonviolent Crime | Firearm (Any Intent) | Nonfirearm | |
| | | Assault | Self-Inflicted | | | | Assault | Self-Inflicted |
| **History of arrest** | | | | | | | | |
| *Firearm-related or violent crime* | | | | | | | | |
| Yes (n = 5529) | 3.3 (1.3–8.3) | 1.3 (0.9–1.8) | 1.3 (1.0–1.7) | 3.8 (3.4–4.2) | 1.7 (1.6–1.8) | 1.1 (0.5–2.1) | 12.0 (2.8–51.9) | 1.8 (1.1–3.0) |
| No (n = 240 593) | 1.0 (Reference) | 1.0 (Reference) | 1.0 (Reference) | 1.0 (Reference) | 1.0 (Reference) | 1.0 (Reference) | 1.0 (Reference) | 1.0 (Reference) |
| *Nonfirearm nonviolent crime* | | | | | | | | |
| Yes (n = 14 698) | 1.5 (0.6–3.9) | 3.8 (2.7–5.5) | 1.6 (1.3–1.9) | 4.2 (3.7–4.6) | 8.9 (8.5–9.4) | 1.1 (0.7–1.9) | 1.3 (0.3–6.4) | 1.1 (0.7–1.8) |
| No (n = 231 424) | 1.0 (Reference) | 1.0 (Reference) | 1.0 (Reference) | 1.0 (Reference) | 1.0 (Reference) | 1.0 (Reference) | 1.0 (Reference) | 1.0 (Reference) |
| **History of diagnosis of psychiatric disorder** | | | | | | | | |
| Substance use disorders (n = 46 236) | 1.5 (0.7–3.3) | 2.7 (1.9–3.7) | 5.9 (4.7–7.4) | 2.2 (2.0–2.4) | 2.7 (2.6–2.8) | 2.3 (1.6–3.4) | 1.0 (0.3–2.9) | 3.8 (2.6–5.6) |
| Other psychiatric disorders (n = 37 187) | 1.5 (0.4–5.3) | 1.6 (0.9–2.8) | 5.8 (4.5–7.5) | 1.7 (1.5–1.9) | 1.4 (1.3–1.5) | 1.7 (1.1–2.6) | 0.7 (0.1–3.4) | 3.7 (2.4–5.7) |
| None (n = 162 699) | 1.0 (Reference) | 1.0 (Reference) | 1.0 (Reference) | 1.0 (Reference) | 1.0 (Reference) | 1.0 (Reference) | 1.0 (Reference) | 1.0 (Reference) |

sHR = subhazard ratio.
* Values are sHRs (95% CIs), which were determined by using models that also included variables listed in the table and age, sex, payer status, discharge year and season, county of the hospital, and type of index hospitalization. A total of 1807 patients with missing data on sex or discharge season were excluded from these analyses.