Long-term Mortality in Pediatric Firearm Assault Survivors: A Multicenter, Retrospective, Comparative Cohort Study

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ABSTRACT

Objectives: The objective was to determine whether children surviving to hospital discharge after firearm assault (FA) and nonfirearm assault (NFA) are at increased risk of mortality relative to survivors of unintentional trauma (UT). Secondarily, the objective was to elucidate the factors associated with long-term mortality after pediatric trauma.

Methods: This was a multicenter, retrospective cohort study of pediatric patients aged 0 to 16 years who presented to the three trauma centers in San Francisco and Alameda counties, California, between January 2000 and December 2009 after 1) FA, 2) NFA, and 3) UT. The Social Security Death Master File and the California Department of Public Health Vital Statistics (2000–2014) were queried through December 31, 2014, to identify those who died after surviving their initial hospitalization and to delineate cause of death. Multivariate Cox proportional hazards regression was performed to determine associations between exposure to assault and long-term mortality.

Results: We analyzed 413 FA, 405 NFA, and 7,062 UT patients who survived their index hospital visit. A total of 75 deaths occurred, including 3.9, 3.2, and 0.7% of each cohort, respectively. Two-thirds of all long-term deaths were due to homicide. After multivariate adjustment, adolescent age, male sex, black race/ethnicity, and public insurance were independent risk factors for long-term mortality. FA (adjusted hazard ratio [AHR] = 1.8, 95% confidence interval [CI] = 0.82–4.0) and NFA (AHR = 1.9, 95% CI = 0.93–3.9) did not convey a statistically significant difference in risk of long-term mortality compared to UT. Being assaulted by any means (with or without a firearm), however, was an independent risk factor for long-term mortality in the full study population (AHR = 1.9, 95% CI = 1.01–3.4) and among adolescents (AHR = 1.9, 95% CI = 1.01–3.6).

Conclusion: Children and adolescents who survive assault, including by firearm, have increased long-term mortality compared to those who survive unintentional, nonviolent trauma.

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In the first decade of the 21st century, more than 20,000 children died from firearm injuries in the United States.[1] American children account for more than 90% of all children killed by firearms in high-income countries.[2] Pediatric and youth survivors of firearm injury and other forms of assault are at particularly high risk of trauma recidivism.[3–6] Recent evidence suggests that both firearm injury and nonfirearm assault (NFA) patients presenting to an urban emergency department (ED) have higher risk of 5-year mortality in comparison to those who present after motor vehicle collision, and those victimized by firearms have a particularly high risk of death in the first year after their index injury, largely due to homicide by firearm.[7] Research on long-term outcomes among pediatric FA survivors is sparse.

Prior research on pediatric firearm-related injuries has focused on the clinical features and demographics of children cared for in the clinical setting, highlighting that these children tend to be adolescent males[6,8–15] and socioeconomically disadvantaged[6,8,10,13,15] and from racial and ethnic minority groups.[6,8–11,13–15] These factors have also been associated with risk of subsequent firearm injury among pediatric survivors of both assault[4] and firearm injury.[5] In one urban pediatric cohort, the trauma recidivism rate among penetrating trauma patients was about twice that of blunt trauma patients.[3] While the body of literature underscores the disparate health impacts of violence in America, such studies are limited by follow-up periods that were brief[4,6] or did not extend beyond adolescence.[3,5] No studies have examined long-term mortality among pediatric survivors of firearm violence nor compared these outcomes to those who survive other forms of assault and trauma. Understanding the largely unstudied, long-term outcomes for children impacted by gun violence could play an essential role in identifying missed opportunities for prevention and in spurring further research[16] to guide evidence-based policy change and resource allocation.

To this end, we conducted a multicenter, retrospective cohort study examining incidence of posthospital mortality in pediatric FA, NFA, and unintentional trauma (UT) survivors. We aimed 1) to determine whether children who survive to hospital discharge following FA and NFA are at increased risk of all-cause, long-term mortality relative to those who survive UT and 2) to identify factors associated with long-term mortality among pediatric trauma patients. We hypothesized that exposure to assault would be associated with increased risk of long-term mortality among pediatric trauma survivors, in a dose-dependent fashion by assault-exposed cohort.

METHODS

Study Design

This is a multicenter, retrospective, comparative cohort study of pediatric trauma patients. The study was approved by the institutional review boards of the University of California, San Francisco (UCSF), UCSF Benioff Children's Hospital Oakland, Alameda Health System, and the California Health and Human Services Agency, which granted exemption from obtaining informed consent due the minimal risk posed by and the retrospective nature of the research.

Study Setting and Population

We included patients ages 0 to 16 years who presented to the three trauma centers in San Francisco and Alameda counties, California, between January 1, 2000, and December 31, 2009. Subjects were sampled consecutively from the trauma registries of UCSF Benioff Children's Hospital Oakland, Highland Hospital, and Zuckerberg San Francisco General and Trauma Center using International Classification of Diseases, Ninth Revision, external cause of injury codes (ICD-9 E-codes), to create three cohorts of patients: 1) assaulted by firearm (firearm assault [FA]), 2) assaulted by means other than firearm (nonfirearm assault [NFA]), and (3) a comparison cohort who experienced UT. If a patient appeared more than once between 2000 and 2009 in the trauma registries, either due to transfer from one hospital to another in the context of one trauma episode or due to repeat trauma, we included them only in the cohort corresponding to their initial hospital visit. We excluded patients evaluated for suicide and child abuse due to the unique, albeit overlapping, risk factors and causal pathways that they face in relation to subsequent mortality. We also excluded two patients with incomplete identifying information.

We conceptualized the two exposed cohorts as representing exposure to differential severities of community-level violence, with FA being the more violent (and most deadly[17]) and NFA (both blunt and penetrating) being the less violent. The UT cohort represents a non–assault-based, nonviolent form of trauma and serves as an intentionally broad comparison, isolating the impact of violence and minimizing selection bias. To allow for the determination of additional risk and protective factors with respect to long-term mortality, matching was not performed in the selection of the comparison cohort.

Exposure and Covariate Measurement

The first, or primary, ICD-9 E-code was used to allocate subjects to their primary injury mechanism cohort. Firearm injuries are classified by ICD-9 E-codes as assault (E965.0–4; E970–legal intervention), undetermined intent (E986.0–4), self-inflicted (E950–958), and accidental (E922). To ensure capture of children "caught in the crossfire" in their communities as experiencing violence, and given that most accidental firearm injuries occur in the home,[18,19] an a priori decision was made to reclassify the firearm injuries occurring with "undetermined intent" as assault if the injury occurred outside of the home (secondary ICD-9 location of injury code E849.1–9) and as accidental if the injury occurred inside the home (secondary ICD-9 location of injury code E849.0). Aside from firearm injuries, other injuries of undetermined intent were not included in the cohorts. The codes used for sampling and classification are shown in Data Supplement S1 (available as supporting information in the online version of this paper, which is available at http://onlinelibrary.wiley.com/doi/10.1111/acem.13631/full). To determine whether our survival analysis would be affected by this injury classification approach, we performed two sensitivity analyses, alternatively classifying all of the undetermined intent subjects as either assault or accidental.

Clinical and demographic covariates at the time of index visit were obtained from the trauma registry and medical record. The clinical variables included injury severity score, severe injury severity score (>15), location (s) of injury, mechanism of NFA, mechanism of UT, medical comorbidities, mode of arrival, disposition from the ED, date of injury, hospital disposition, length of stay (LOS), intensive care unit LOS, and whether or not the patient died during the index visit. Patients who appeared on the trauma registries for two hospitals due to transfer during a single trauma episode were considered to have one hospitalization for the purposes of determining whether they died prior to hospital discharge. Two patients who were transferred outside of the three study hospitals after one-night stay in the intensive care unit were deemed to have died on index visit by unanimous consensus of the lead authors (AS, IHY, HJA, JF) after careful review of their case details. We performed a sensitivity analysis to determine whether this decision altered the study findings.

The potential demographic covariates included age, sex, race/ethnicity, insurance status, year of index visit, hospital of index visit, and violent crime index (VCI; number of violent crimes per 100,000 population) by city of residence. City of residence was based on the address available from the trauma registry or medical record at or nearest to the time of index visit. To standardize for changes in crime rate over the study period, the mean of the VCIs from the years 2000, 2005, and 2010 was calculated for each city[20] and this mean VCI was utilized in the multivariate analysis. Additional identifying variables collected for the purpose of matching subjects with the outcome databases included name, date of birth, social security number (SSN), and mother or father's name, as available.

Ascertainment of Outcomes

The primary outcome was hazard of all-cause mortality in person-years from the date of injury through December 31, 2014. Death was ascertained through two outcome databases, the Death Master File (DMF) of the USA Social Security Administration and the California Department of Public Health Vital Statistics death records from 2000 through 2014. We first queried both databases by SSN and subsequently queried the California Vital Statistics records by first name, last name, sex, and date of birth for all subjects without a SSN (n = 4,058). Death was confirmed with an exact match of SSN or an exact match of first and last name, sex, and date of birth. Cause and date of death were recorded for those who died. Three additional probabilistic matches were also considered in which first name, last name, or date of birth varied by one or two characters. All deaths were reviewed by an investigator (AS) to ensure true matches, and two matches were deemed to be false-positives (e.g., a 4-month-old who "died" at 2 months of age and has had multiple recent hospital visits in the medical record). We did not match with the DMF based on name, as the large number of records in the data set would result in a high potential for false positives. To minimize false-negative determination of death, subjects without a SSN were excluded from the outcome analyses if they were not known to have an address in California at the time of their index injury.

Planned secondary outcomes included death by homicide, recorded from the mortality databases;

subsequent FA and subsequent trauma, ascertained in subjects with multiple different trauma registry appearances over time; and number of ED visits and hospital admissions during 5-year follow-up, obtained through queries of medical billing records. Additional reported outcomes included follow-up duration, years to death, age at enrollment among those who died following index visit, and age at death.

Data Analysis

Outcome data among subjects who survived their index visit were summarized by primary injury cohort using counts and proportions for categorical variables and medians with interquartile ranges (IQRs) for continuous variables. Bivariate comparisons of outcome variables were made among the three cohorts using chi-square and analysis of variance tests, as appropriate.

We performed a Cox proportional hazards regression to determine associations between exposure to violence and long-term mortality using predetermined, purposeful selection of covariates, including potential confounders as well as suspected risk factors for mortality based on biologic plausibility and prior literature. In addition to the primary injury exposure, the covariates included in the model were age by strata (0–5, 6–11, and 12–16 years),[21] sex, race/ethnicity, presence of any medical comorbidities, insurance status, severe injury severity score > 15, VCI by city of residency, year of index visit, hospital of visit, injury location involving the head, and whether or not there were multiple injury locations. We report unadjusted as well as multivariate, adjusted hazard ratios (AHRs) with their 95% confidence intervals (CIs) for the primary exposure and each covariate. Kaplan-Meier survival curves were created for the three cohorts, in which the risk period began on the date of index visit and ended on the date of death or December 31, 2014.

We conducted planned, stratified analyses by age strata to evaluate age as an effect modifier, including the Cox proportional hazards regression and the Kaplan-Meier survival analysis. Finally, we performed a post hoc analysis combining the two assault cohorts into a single assault cohort and determining unadjusted and AHRs in comparison with the UT cohort utilizing an otherwise equivalent Cox proportional hazards model.

Missing data were coded as missing and no values were imputed. A significance level of 0.05 was used and all hypothesis tests were two-sided. All statistical analyses were performed using SAS software (Version 9.4, SAS Institute Inc.).

RESULTS

Baseline Characteristics of Cohorts

Sampling from the trauma registries yielded 8,415 unique and identifiable subjects meeting inclusion criteria. After excluding patients evaluated for suicide (n = 15) and child abuse (n = 149), the cohorts included 461 FA patients, 417 NFA patients, and 7,373 UT patients. Of eligible subjects, 7,880 (97.3%) had adequate identifying information for long-term follow-up, after exclusion of 150 individuals who were deemed to have died during their index visit. The final cohorts involved in the outcome and survival analyses included 413 FA, 405 NFA, and 7062 UT patients, respectively (Figure 1). Demographic and clinical features of the cohorts, including death during index visit, are displayed in Table 1.

The cohorts were significantly different by age, sex, race/ethnicity, insurance status, VCI by city of residence, injury location, injury severity score, hospital LOS, and death during index visit. The assault cohorts tended to be older (median age = 15.4 years vs. 8.6 years), had higher percentages of male patients, and lived in cities with higher violent crime indices. The majority of children in the FA cohort were black/non-Hispanic (65.5%). The racial/ethnic distribution was more uniform in the other cohorts with black/non-Hispanic (38.6%) and white/non-Hispanic (28.3%) representing the highest proportion of the NFA and UT cohorts, respectively. Most NFA (56.1%) and UT (51.6%) patients had injuries involving the head whereas FA patients were more commonly injured in their extremities (41.6%), chest/trunk and/or abdomen/pelvis (37.5%), and neck/back/spine (10.2%). Nearly 30% of all three cohorts had multiple injury locations. In comparison with the other cohorts, patients who experienced FA had higher average injury severity scores, had longer hospital LOS, and had higher likelihood of dying during their index visit.

Mechanism of injury among the 417 NFA patients was predominantly blunt trauma, including 164 children (39.3%) who were punched or kicked and 68 (16.3%) who were struck by an object. Remarkably, nearly two of five (39.2%) in this cohort experienced assault by penetrating trauma, including stabbing by knife and assault by air rifle. Among the UT cohort,

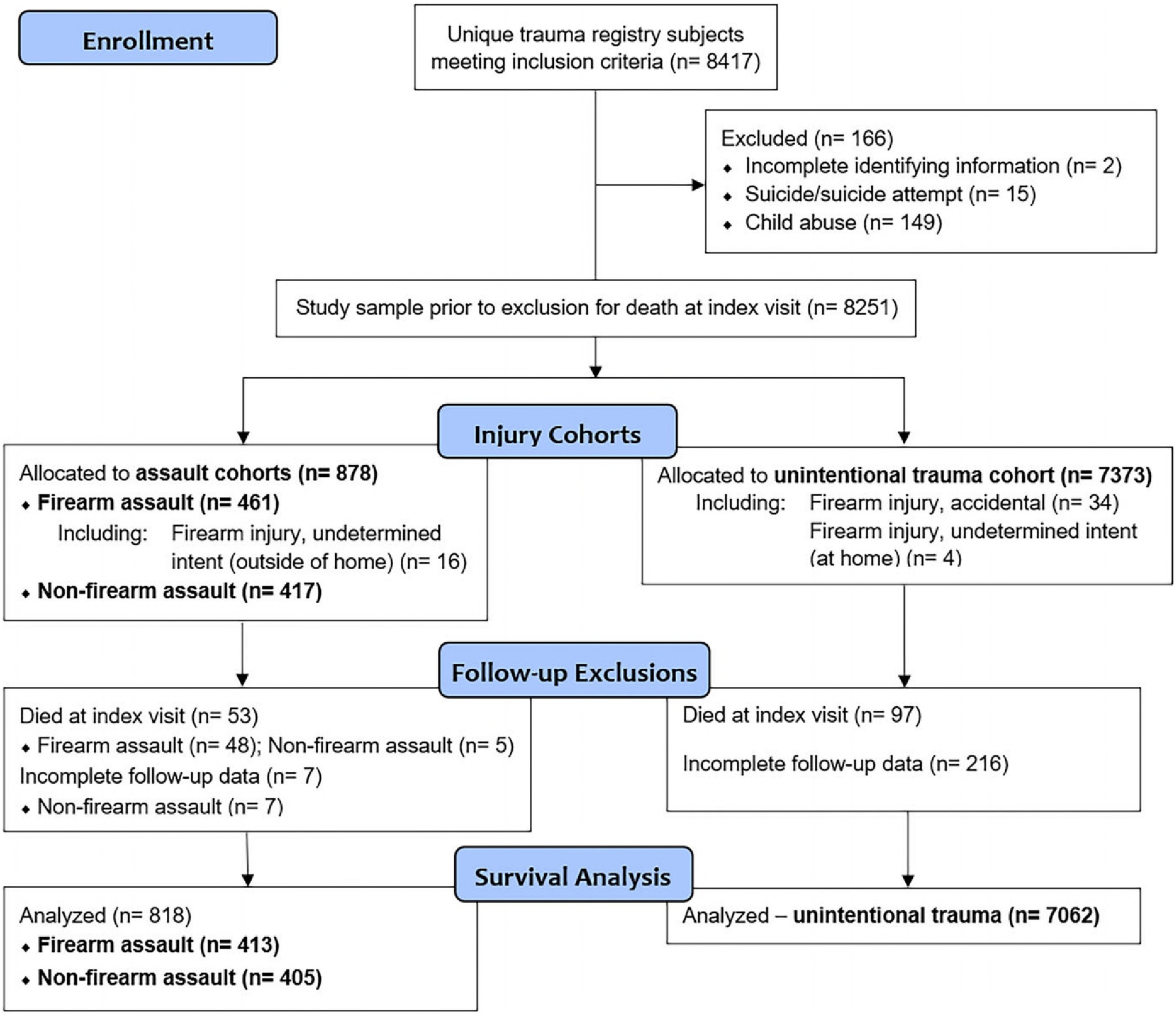

Figure 1. Enrollment flow diagram.

mechanism of injury was mostly distributed among fall (27.6%), automobile striking pedestrian or bicyclist (27.1%), and motor vehicle collisions (26.4%).

Long-term Outcomes and Survival Analysis

Cohorts had median durations of follow-up from 8.2 to 9.3 years. Among those who survived to hospital discharge, 16 (3.9%) of the firearm patients, 13 (3.2%) of the NFA patients, and 46 (0.7%) of the UT patients died during the follow-up period. Deaths occurred a median of 4.6, 5.3, and 5.9 years following index injuries, in each respective cohort. Two-thirds of all long-term deaths after surviving index injury were due to homicide, which was by far the most common cause of long-term mortality in all three cohorts. Long-term outcomes by cohort are displayed in Table 2.

Firearm assault patients had high rates of subsequent ED utilization, with 158 (38.3%) patients having at least one ED visit following their index injury. This cohort also had significantly higher rates of subsequent hospital admission, with 59 (14.3%) of these patients having at least one inpatient admission following their index hospitalization. Both of the assault cohorts had higher rates of trauma recidivism within the three study hospitals compared to the UT cohort. Fifteen (3.6%) FA victims and 14 (3.5%) NFA victims reappeared in a study trauma registry for trauma of any type before their 17th birthday. Eleven (73%) and six (43%) of these later traumas, respectively, were due to assault by firearm.

Results of the long-term mortality analysis reporting univariate and multivariate hazard ratios with 95%

Table 1
Baseline Characteristics of Cohorts

	Cohort			
Variable	FA (*n* = 461)	NFA (*n* = 417)	UT (*n* = 7,373)	p-value
Age (years)	15.5 (14.4–16.2)	15.1 (13.9–16.1)	8.6 (3.8–12.8)	<0.0001
Male	381 (82.6)	342 (82.0)	4,721 (64.0)	<0.0001
Race/ethnicity				<0.0001
White, non-Hispanic	21 (4.6)	46 (11.0)	2,083 (28.3)	
Black, non-Hispanic	302 (65.5)	161 (38.6)	1,703 (23.1)	
Hispanic	105 (22.8)	141 (33.8)	1,812 (24.6)	
Asian/Pacific Islander	17 (3.7)	37 (8.9)	897 (12.2)	
Other	16 (2.6)	20 (4.8)	588 (8.0)	
Insurance status				<0.0001
Private	95 (20.6)	118 (28.3)	3,069 (41.6)	
Medicaid/MediCal/Medicare	212 (46.0)	152 (36.4)	2,370 (32.1)	
Uninsured	88 (19.1)	64 (15.3)	882 (12.0)	
VCI, by city of residence (violent crimes/100,000 population)	1,003 (±416)	877 (±471)	650 (±491)	<0.0001
Medical comorbidity	10 (14.3)	34 (22.4)	537 (11.1)	<0.0001
Hospital of index visit				<0.0001
UBCHO (formerly CHRCO)	65 (14.1)	146 (35.0)	4,823 (65.4)	
Highland (formerly ACMC)	203 (44.0)	119 (28.5)	377 (5.1)	
ZSFG (formerly SFGH)	193 (41.9)	152 (36.4)	2,173 (29.5)	
Mode of arrival				<0.0001
Ambulance	281 (61.0)	283 (67.9)	3,967 (53.8)	
Walk-in/ambulatory	72 (15.6)	50 (12.0)	494 (6.7)	
Helicopter	10 (2.2)	8 (1.9)	846 (11.5)	
Transfer/other facility	7 (1.5)	15 (3.6)	845 (11.5)	
Injury Severity Score	13.8 (±15.1)	6.7 (±7.9)	7.0 (±7.9)	<0.0001
Injury location				
Head	72 (15.6)	234 (56.1)	3,805 (51.6)	<0.0001
Neck/back/spine	47 (10.2)	17 (4.1)	177 (2.4)	<0.0001
Chest/trunk	88 (19.1)	72 (17.3)	782 (10.6)	<0.0001
Abdomen/pelvis	85 (18.4)	24 (5.8)	466 (6.3)	<0.0001
Extremity	218 (47.3)	90 (21.6)	177 (2.4)	<0.0001
Other	34 (7.4)	74 (17.7)	1,378 (18.7)	<0.0001
Multiple locations	138 (29.9)	124 (29.7)	2,114 (28.7)	0.77
Disposition from ED				<0.0001
Admit, ward/step-down	99 (21.5)	94 (22.5)	1,668 (22.6)	
Admit, ICU/OR	149 (32.3)	80 (19.2)	1,867 (25.3)	
Posthospital (includes home)	187 (40.6)	230 (55.2)	3,313 (44.9)	
Morgue	25 (5.4)	2 (0.5)	26 (0.4)	
Hospital LOS (days)	5.0 (±11.6)	2.6 (±5.3)	2.6 (±4.2)	<0.0001
ICU LOS (days)	1.5 (±6.0)	0.5 (±1.9)	1.5 (±30.8)	0.62
Died during index visit	48 (10.3)	5 (1.2)	97 (1.3)	<0.0001

Data are reported as median (IQR), *n* (%), or mean (±SD).
ACMC = Alameda County Medical Center; CHRCO = Children's Hospital and Research Center Oakland; FA = firearm assault; Highland = Highland Hospital; ICU = intensive care unit; IQR = interquartile range; LOS = length of stay; NFA = nonfirearm assault; OR = operating room; SFGH = San Francisco General Hospital; UBCHO = UCSF Benioff Children's Hospital Oakland; UT = unintentional trauma; VCI = violent crime index; ZSFG = Zuckerberg San Francisco General and Trauma Center.

CIs can be seen in Table 3. Hospital and year of index visit are not included in the table but were adjusted for in the model. After multivariate adjustment with the Cox proportional hazards model, adolescent age (AHR = 2.9, 95% CI = 1.3–6.6), male sex (AHR = 3.0, 95% CI = 1.3–7.1), black race/ethnicity (AHR = 3.3, 95% CI = 1.2–9.4), and public insurance (AHR = 2.5, 95% CI = 1.2–5.2) were

Table 2
Outcomes Among Subjects Surviving Index Visit

Variable	Cohort			
	FA (*n* = 413)*	NFA (*n* = 405)*	UT (*n* = 7,062)*	p-value
Follow-up period (years)	8.2 (6.6–9.9)	9.0 (7.1–11.6)	9.3 (7.1–11.8)	<0.0001
Subjects with subsequent ED visits	158 (38.3)	38 (9.4)	849 (12.0)	<0.0001
Subjects with subsequent hospital admissions	59 (14.3)	20 (4.9)	424 (6.0)	<0.0001
Subjects with subsequent trauma	15 (3.6)	14 (3.5)	80 (1.1)	<0.0001
Years to subsequent trauma	0.6 (0.4–1.1)	0.8 (0.5–2.5)	1.9 (0.6–3.6)	0.006
Subjects with subsequent firearm injury	11 (2.7)	6 (1.5)	25 (0.4)	<0.0001
Years to subsequent firearm injury	0.5 (0.4–1.1)	0.8 (0.6–2.2)	2.3 (0.6–4.2)	0.02
Death after index visit	16 (3.9)	13 (3.2)	46 (0.7)	<0.0001
By homicide	12 (75.0)	11 (84.6)	27 (58.7)	<0.0001
By suicide	0 (0)	1 (7.7)	3 (6.5)	0.18
By accidental injury	2 (12.5)	0 (0)	4 (8.7)	0.008
By nontraumatic cause	2 (12.5)	1 (7.7)	12 (26.1)	<0.0001
Age at enrollment in those who died after index visit	15.4 (15.0–16.0)	15.1 (13.9–16.2)	13.4 (11.1–14.8)	0.006
Years to death	4.6 (3.6–6.8)	5.3 (4.5–7.6)	5.9 (4.4–8.7)	0.56
Age at death	20.0 (18.1–22.2)	19.8 (16.6–22.7)	19.2 (17.1–21.5)	0.0004

Data are reported as median (IQR) or *n* (%).
IQR = interquartile range; FA = firearm assault; NFA = nonfirearm assault; UT = unintentional trauma.
*Excluding subjects with inadequate identifying information for long-term follow-up.

independent risk factors for long-term mortality. In comparison with the UT cohort, neither FA patients (AHR = 1.8, 95% CI = 0.82–4.0) nor NFA patients (AHR = 1.9, 95% CI = 0.93–3.9) experienced a statistically significant difference in long-term mortality risk. However, in post hoc analysis, exposure to any type of assault (with or without a firearm) was an independent risk factor for mortality after survival to hospital discharge (AHR = 1.9, 95% CI = 1.01–3.4). The Kaplan-Meier survival curves by cohort can be seen in Figure 2. There is a significant difference in the curve trajectories ($p < 0.0001$).

Our sensitivity analyses, respectively, showed that our a priori classification approach for subjects who experienced firearm injury by undetermined intent had no impact on the conclusions of the survival analysis and that our determination of death on index visit for two patients transferred to outside facilities altered the study findings toward the null hypothesis.

Age-stratified Analysis: Adolescent Outcomes

All 29 of the assault survivors as well as 30 (65%) of the UT survivors who died on follow-up were young adolescents, aged 12 to 16, at the time of their index injury and enrollment into their respective study cohort. Among those who survived their index injury, 4.1% of adolescents assaulted by firearm, 3.6% of adolescents assaulted by means other than firearm, and 1.4% of adolescents who experienced UT died. Adolescents aged 12 to 16 years who survived FA and NFA had no statistically significant difference in long-term mortality compared to nonassaulted adolescents (AHR = 1.9, 95% CI = 0.83–4.3; and AHR = 1.9, 95% CI = 0.92–4.1, respectively), similar to the nonstratified cohort. As in the broader study population, however, adolescents who were assaulted by any means (with or without a firearm) carried a significantly higher risk of long-term mortality (AHR = 1.9, 95% CI = 1.01–3.6). Due to an overall low assault exposure and death incidence among younger children, the data were not robust enough to perform the Cox proportional hazards analysis in the younger age strata nor to fully evaluate age as an effect modifier of the relationship between exposure to violence and long-term mortality.

DISCUSSION

Among pediatric trauma patients aged 0 to 16 seen at three trauma centers in our study population, children and adolescents who present for and survive after assault with or without a firearm had an approximately 3% to 4% risk of mortality over a median of 8 to 9 years. Most long-term deaths among these patients, regardless of the intent behind the index injury, were

Table 3
Cox Proportional Hazards Regression Results With Unadjusted and AHRs for Death After Surviving Index Visit*

Variable	Unadjusted Hazard Ratio (95% CI)	Multivariate, AHR (95% CI)
Primary injury cohort		
UT	1 (reference)	1 (reference)
FA	6.9 (3.9–12.2)†	1.8 (0.82–4.0)
NFA	5.0 (2.7–9.2)†	1.9 (0.93–3.9)
Age strata (years)		
6–11	1 (reference)	1 (reference)
12–16	3.5 (2.0–6.3)†	2.9 (1.3–6.6)‡
0–5	0.13 (0.03–0.57)†	0.11 (0.01–0.9)‡
Sex		
Female	1 (reference)	1 (reference)
Male	4.4 (2.1–9.2)†	3.0 (1.3–7.1)‡
Race/ethnicity		
White, non-Hispanic	1 (reference)	1 (reference)
Black, non-Hispanic	8.1 (3.5–18.8)†	3.3 (1.2–9.4)‡
Hispanic	2.0 (0.73–5.4)	0.92 (0.28–3.1)
Asian/Pacific Islander	1.5 (0.42–5.3)	0.70 (0.13–3.7)
Other	2.0 (0.60–6.4)	1.5 (0.36–6.6)
Comorbidities		
No medical comorbidity	1 (reference)	1 (reference)
Medical comorbidity	1.4 (0.7–2.8)	0.81 (0.39–1.7)
Insurance status		
Private insurance	1 (reference)	1 (reference)
Medicaid/MediCal/Medicare	3.4 (1.8–6.2)†	2.5 (1.2–5.2)‡
Uninsured	1.3 (0.51–3.5)	0.63 (0.14–2.9)
Injury Severity Score		
≤15	1 (reference)	1 (reference)
>15	1.3 (0.64–2.8)	0.81 (0.35–1.9)
VCI		
VCI (per 1-point increase)	1.001 (1.000–1.001)†	1.000 (0.999–1.001)
Injury location		
No injury involving head	1 (reference)	1 (reference)
Injury involving head	0.66 (0.42–1.1)	0.87 (0.58–1.9)
Multiple vs. isolated injury		
Isolated injury location	1 (reference)	1 (reference)
Multiple injury locations	1.2 (0.72–1.9)	0.95 (0.52–1.7)

AHR = adjusted hazard ratio; VCI = violent crime index.
*Excluding subjects with inadequate identifying information for long-term follow-up.
†$p < 0.01$.
‡$p < 0.05$.

due to homicide (66.7%). Adolescent age, male sex, black race/ethnicity, and public insurance status were independent risk factors for mortality after surviving trauma. Importantly, these variables were also those that were associated with being a victim of assault in our sample, mirroring those described in prior studies.[5,6,8–15] On the other hand, our study did not detect additional independent risk posed separately by exposure to FA or NFA nor a dose-dependent association with mortality risk by assault-exposed cohort. However, being assaulted by any means (with or without a firearm) independently conveyed nearly twice the risk of long-term mortality compared to experiencing unintentional, nonviolent trauma (AHR = 1.9, 95% CI = 1.01–3.4).

Our findings are consistent with those of two recent cohort studies that reported increased all-cause[7] and firearm-related[22] mortality among both firearm injury[7,22] (AHR = 2.54 and 4.3, 95% CI = 1.41–4.59 and 1.3–14.1, respectively) and NFA survivors[7]

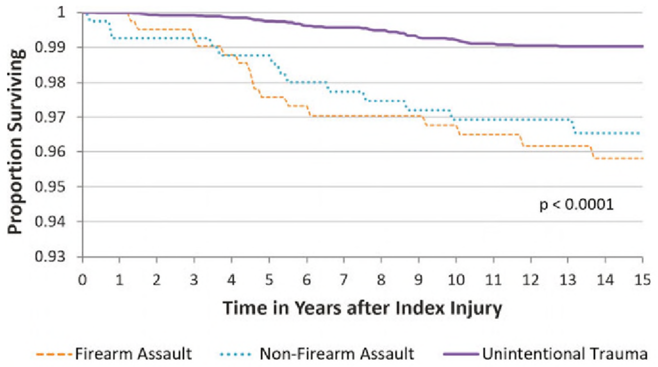

Figure 2. Kaplan-Meier survival curves by cohort after excluding those who died during index visit. Subjects with inadequate identifying information for long-term follow-up were also excluded.

(AHR = 1.64, 95% CI = 1.01–2.68) compared to accidentally injured[7] and noninjured[22] patients, further expanding this understanding of long-term risk to include the pediatric population. In the recent investigation by Fahimi et al.,[7] nonfatal firearm injury and NFA both carried a 5% risk of death at 5 years; our study further underscores that children and adolescents who are seen in urban trauma centers for either FA or NFA may both be at similarly high risk for mortality over time. However, while most deaths in the former study's surviving firearm injury cohort occurred in the first year after index injury, the median time to death among FA and NFA subjects in the present study was 4.6 and 5.3 years, respectively. This potential difference in the epidemiology of recidivism between young adolescents and young adults following FA is particularly salient when considering secondary prevention interventions and warrants further study.

Mediators of the increased risk of long-term mortality among the assault survivors in our study might include risky coping behaviors, such as drug use and gang membership, as well as insecurity precluding prosocial behavior such as health care seeking and school attendance. For instance, while poor academic performance[23] and lack of commitment to school[24] have been described as predictors of youth violence, teacher support[25,26] and perceived safety at school[26] are protective against the consequences of exposure to community violence. Repeat exposure to violent trauma in late adolescence and young adulthood seems to play a central role in conveying long-term mortality risk, and the recidivism rates among our assault (3.6 and 3.4%) and unintentional injury (1.1%) cohorts mirrored those described in prior studies.[3,6] However, retrospective determinations of violent injury recidivism likely underestimate risk. For example, in one prospective cohort of assault-exposed youth aged 14 to 24 years, 59% experienced subsequent exposure to gun violence (either aggression or victimization) within 2 years of their initial ED visit.[4] In contrast with their influence on short-term mortality,[7,27] clinical and injury-specific covariates were not significant predictors of long-term mortality in our sample and, therefore, medical complications of more severe injuries were unlikely to play an important role in conveying this increased risk. On the other hand, given that falling victim to firearm or NFA often reflects community-level violence, we hypothesize that community-level factors associated with firearm injury[5,6,15] and homicide[28,29] may play a more important role in long-term mortality risk than the individual-level factors examined in this study. Future research should address this gap in the literature.

While it may seem intuitive that pediatric victims of community violence, and particularly firearm violence, may be a high-risk population, our findings are notable. They contribute meaningfully to the body of literature by expanding our understanding of long-term outcomes among children and adolescents who survive assault. Reflecting patients from three major trauma centers, including a stand-alone children's hospital and two county hospitals, our findings are likely generalizable to hospitals in similar urban communities that face high rates of violence. By reinforcing the motivation for health care, public health, education, social service, and law enforcement communities to target the most at-risk children and adolescents, our hope is that the growing body of evidence will inform the ongoing development of primary and secondary prevention interventions, such as risk factor modification,[30] gun safety laws,[31,32] asset development and supportive services,[33,34] mentoring,[35] and/or motivational interviewing and harm reduction.[36,37]

LIMITATIONS

This study has a number of limitations. First, the relationship between violence and mortality risk is a complex one, and there is certainly unmeasured confounding for which we were unable to control. We do believe that we addressed the most important confounders as evidenced by the sizeable changes in effect sizes after multivariate adjustment. Furthermore, our purposeful, rather than stepwise, approach to covariate selection for the model decreased the likelihood of finding spurious associations. We hope to address unmeasured confounding further with a future study incorporating neighborhood-level factors into the model among the same cohort of patients.

In addition, the overall low mortality rate as well as the relatively short follow-up period inhibited our ability to fully elucidate age as an effect modifier of the relationship of exposure to violent injury on later mortality. Given that most deaths occurred during or after adolescence, the short follow-up period likely had a disproportionate impact on the youngest subjects, who were less likely to reach adolescence by the end of the follow-up period. Therefore, although assault by any means was associated with higher risk of long-term mortality across the entire study population after adjusting for age as well as within the adolescent stratum, we were unable to determine whether or not younger children were separately at higher risk of long-term mortality after assault.

Finally, although we made every effort to ensure the reliability of our data and the accuracy of our outcome matching, we cannot be certain that every death was captured. To be captured in the outcome databases, subjects had to either have a SSN or be living in California at the time of their death. We addressed this limitation by excluding subjects without a SSN from the long-term analysis if they were not known to have an address in California at the time of their index injury. There was no significant difference between cohorts with regards to exclusion from the long-term analysis, so we do not anticipate that these biased our findings. Furthermore, because coding for cause of death is based on coroners' reports and death certificates, there is a possibility of inaccuracies, including in the determination of homicide.[38,39] We cannot be certain whether a death coded as homicide represents the immediate impact of an assault or the later sequelae of a prior assault that occurred months or years earlier.

CONCLUSIONS

In summary, among children and adolescents seen in urban trauma centers, those who survive after exposure to assault, including by firearm, have increased long-term mortality compared to those who survive unintentional, nonviolent trauma. Our findings again highlight the disparities that black adolescent males and the socioeconomically disadvantaged face with regard to community violence and premature mortality. In light of our findings, and particularly given that so many of these deaths are due to homicide, the need for prospective studies and the implementation of evidence-based programs and policies is urgent.

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Supporting Information

The following supporting information is available in the online version of this paper available at http://onlinelibrary.wiley.com/doi/10.1111/acem.13631/full

Data Supplement S1. ICD-9 E-code primary injury mechanism cohort allocation.