

Gunshot Injuries in Children Served by Emergency Services



WHAT'S KNOWN ON THIS SUBJECT: Gunshot injuries are an important cause of preventable injury and mortality in children, with emergency services often providing the initial care for patients. However, there is little recent population-based research to guide public health, injury prevention, and health policy efforts.



WHAT THIS STUDY ADDS: Gunshot injuries are uncommon in children, but cause greater injury severity, need for major surgery, mortality, and costs compared with other injury mechanisms. There is also large variation in the population-adjusted incidence of pediatric gunshot injuries between regions.

abstract



OBJECTIVE: To describe the incidence, injury severity, resource use, mortality, and costs for children with gunshot injuries, compared with other injury mechanisms.

METHODS: This was a population-based, retrospective cohort study (January 1, 2006–December 31, 2008) including all injured children age ≤ 19 years with a 9-1-1 response from 47 emergency medical services agencies transporting to 93 hospitals in 5 regions of the western United States. Outcomes included population-adjusted incidence, injury severity score ≥ 16 , major surgery, blood transfusion, mortality, and average per-patient acute care costs.

RESULTS: A total of 49 983 injured children had a 9-1-1 emergency medical services response, including 505 (1.0%) with gunshot injuries (83.2% age 15–19 years, 84.5% male). The population-adjusted annual incidence of gunshot injuries was 7.5 cases/100 000 children, which varied 16-fold between regions. Compared with children who had other mechanisms of injury, those injured by gunshot had the highest proportion of serious injuries (23%, 95% confidence interval [CI] 17.6–28.4), major surgery (32%, 95% CI 26.1–38.5), in-hospital mortality (8.0%, 95% CI 4.7–11.4), and costs (\$28 510 per patient, 95% CI 22 193–34 827).

CONCLUSIONS: Despite being less common than other injury mechanisms, gunshot injuries cause a disproportionate burden of adverse outcomes in children, particularly among older adolescent males. Public health, injury prevention, and health policy solutions are needed to reduce gunshot injuries in children. *Pediatrics* 2013;132:862–870

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KEY WORDS

trauma, children, health services, violence

ABBREVIATIONS

AIS—abbreviated injury scale
CI—confidence interval
ED—emergency department
EMS—emergency medical services
GCS—Glasgow Coma Scale
ICD-9-CM—*International Classification of Diseases, Ninth Revision, Clinical Modification*
ISS—injury severity score
WESTRN—Western Emergency Services Translational Research Network

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Gunshot-related injuries are a leading cause of death and non-fatal injury among children and adolescents in the United States.¹ Gunshot injuries rank second only to motor vehicle crashes as a cause of death for children ages 15 to 19 years.¹ From 2001 through 2010, 29 331 children age 0 to 19 years died of gunshot-related injuries.¹ Another 155 000 children were injured seriously enough to undergo treatment in emergency departments (EDs).¹ After peaking in 1994, the gunshot-related mortality rate for children ages 0 to 19 years fell 54.6% by 2003, but has remained almost unchanged since.¹

Pediatric gunshot-related injury and death has been the subject of several population-based epidemiologic studies from the mid-1980s through 2002.²⁻⁸ Other studies during this time period grouped gunshot injuries with other forms of intentional injury.^{9,10} More recent population-based research has been limited and focused exclusively on mortality^{11,12} or was restricted to hospital-based samples.¹³⁻¹⁵ Data from the National Violent Death Reporting System provide insight into the problem,¹⁶ although only include fatalities. Thus, there remains a lack of recent population-based research on gunshot-related injuries in children, with almost no studies evaluating or integrating the important role of emergency medical services (EMS) in the care of these patients.

To address these important research gaps, we conducted a population-based study of injured children served by EMS agencies in 5 regions of the western United States, matched to ED and hospital records. By using a large sample starting with 9-1-1 EMS contact, we compared children with gunshot injuries to those with other injury mechanisms regarding incidence, injury severity, hospital interventions, mortality, and costs.

METHODS

Study Design

This was a multiregion, population-based, retrospective cohort study using the Western Emergency Services Translational Research Network (WESTRN). Eleven institutional review boards in 5 regions approved this protocol and waived the requirement for informed consent.

Study Setting

The study included injured children evaluated by 47 EMS agencies serving more than 2.2 million children¹⁷ in 5 regions and transporting to 93 hospitals (11 Level I, 5 Level II, and 77 non-tertiary community and private hospitals) over a 3-year period. The 5 regions included: Portland, OR/Vancouver, WA (4 counties); King County, WA; Sacramento, CA (2 counties); Santa Clara, CA (2 counties); and Denver County, CO. Each of these regions represents a predefined geographic "footprint" consisting of a central metropolitan area and surrounding areas (suburban and some rural), defined by EMS agency service areas.

Patient Population

We included all injured children up to age 19 years for whom the 9-1-1 EMS system was activated within the 5 predefined geographic regions from January 1, 2006 through December 31, 2008. Injured children were identified by provider primary impression in EMS patient care reports. Specifying the sample in this manner allowed us to identify a broad, population-based, out-of-hospital injury cohort of children served by EMS providers in multiple trauma systems. We excluded children transferred between hospitals without an initial presentation involving EMS and 9-1-1 calls without patient contact.

Variables

We recorded out-of-hospital variables from EMS electronic health records exported from each EMS agency and

transmitted to a central data coordinating center. In regions where multiple EMS agencies (eg, fire departments and private ambulance agencies) care for the same patients, we matched EMS records at the patient level. We have previously detailed and rigorously evaluated the methods for constructing this cohort¹⁸ and have validated the all-electronic data collection processes used in this study.¹⁹

The primary exposure variable of interest was mechanism of injury (15 categories), as recorded by EMS providers. EMS agencies collected mechanism of injury based on standardized categories outlined in the National EMS Information System²⁰ for "cause of injury." The guidelines for collecting this variable in electronic patient care reports were based on standard EMS training and charting practices in these agencies. Because of small numbers of children in certain categories, we collapsed the mechanism variable into 6 categories: gunshot (including powder-charged and air guns), cut or piercing (eg, stabbing), occupant motor vehicle crashes, pedestrians struck by motor vehicles, falls, struck by blunt object (eg, assaults), and "other" mechanisms.

To evaluate the mechanism of injury term, we matched EMS chart narratives available from 2 sites (Portland, OR and Denver, CO) by using all available sources of EMS patient care reports (fire agencies, ambulance agencies, and base-hospital phone records transcribed from EMS calls). Chart narratives provide contextual descriptions of the scene, patient, and circumstances surrounding the injury event. We assessed inter-rater reliability by randomly sampling 20% of patients with non-missing values for mechanism and a matched chart narrative ($n = 1915$). An investigator blinded to the EMS-coded mechanism term abstracted these records for mechanism of injury by using the same categories. We then compared the 2 independent

mechanism terms using κ scores, which ranged from 0.64 (“other” category) to 0.93 (motor vehicle occupant). In addition, we abstracted all available chart narratives for patients with gunshot injuries to estimate the proportion of injuries from powder-charged firearms versus air guns (including BB, pellet, and paint ball guns) in the sample.

We also collected out-of-hospital disposition, EMS transport mode, patient demographics (age, gender), field trauma activation status (a dichotomous measure of patients meeting predefined field trauma triage criteria), initial field physiologic measures (systolic blood pressure, Glasgow Coma Scale [GCS] score, respiratory rate), out-of-hospital procedures (intubation attempt, intravenous line placement), and transport destination (including hospital type). We categorized hospital destinations as major trauma centers (Level I and II trauma hospitals) based on their American College of Surgeons accreditation status and state-level designations versus non-tertiary hospitals. We also recorded the occurrence of inter-hospital transfer after initial EMS transport.

Outcomes

Hospital outcome measures included abbreviated injury scale (AIS) score, injury severity score (ISS), surgical interventions, blood transfusion, in-hospital mortality, and average per-patient acute care costs. To determine hospital outcomes, we matched EMS records to hospital records using probabilistic linkage (LinkSolv v8.2; Strategic Matching, Inc, Morrisonville, NY). Record linkage methodology has been used to link large EMS data files to hospital records in previous studies,²¹ validated for matching ambulance records to trauma registry data²² and rigorously evaluated in this database.¹⁸ Sources of electronic hospital records included local trauma registries, state

hospital discharge databases, and state ED databases (3 sites did not have ED data available). Because AIS and ISS are not collected in state discharge or ED databases, we used International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) codes and a mapping function (ICDPIC, Stata v 11; StataCorp, College Station, TX) to convert ICD-9-CM diagnosis codes to AIS and ISS values.²³ Previous studies have validated the process of mapping administrative diagnosis codes to generate anatomic injury scores^{24,25} and we have previously validated ICDPIC-generated injury scores against chart-abstracted scores in this database.²⁶ We defined “serious injury” as an AIS ≥ 3 in specific body regions and ISS ≥ 16 for overall injury severity.²⁷ We categorized major surgical interventions by body region: abdominal, thoracic, spine, brain, neck, and vascular (including interventional radiology procedures). The methods for calculating per-patient acute care costs are described in the Supplemental Information; we did not evaluate costs beyond the acute care period.

Data Analysis

We used descriptive statistics to characterize the sample and compare children with gunshot injuries versus those injured by other mechanisms. We calculated annual incidence estimates by averaging the number of children injured by each mechanism over the 3-year period (numerator) and by using 2010 census data¹⁷ for each region to define the at-risk population of children (denominator).

To preserve the population-based sampling design and minimize bias in the analysis, we used multiple imputation²⁸ to handle missing values for important out-of-hospital variables. These variables included mechanism of injury (13% missing), physiologic measures (16%–29% missing), and EMS procedures (3%–8% missing). Details on the use of

multiple imputation in this study are included in the Supplemental Information. For analyses of hospital measures, we restricted the sample to children transported to acute care hospitals with matched hospital records available. As a sensitivity analysis, we recalculated estimates for hospital measures by using all transported children (matched and unmatched to hospital records) with multiple imputation to impute missing hospital outcomes. We managed the database and conducted analyses using SAS (v 9.2, SAS Institute, Cary, NC).

RESULTS

A total of 49 983 injured children age 0 to 19 years were evaluated by EMS providers in the 5 regions over the 3-year period, of whom 505 (1.0%) had gunshot injuries. Among children with gunshot injuries, 421 (83.2%) were between age 15 and 19 years, and 427 (84.5%) were male. For children injured by other mechanisms ($n = 49 478$), 24 283 (49.1%) were between age 15 and 19 years, and 29 003 (58.6%) were male. Among children with gunshot injuries who had an EMS chart narrative available for review ($n = 184$), 36.4% of all children injured by gunshot, there were 27/184 (14.7%) air gun injuries, 156/184 (84.8%) firearm injuries, and 1/184 (0.5%) could not be determined. Children with gunshot injuries had greater out-of-hospital physiologic compromise, required more EMS medical procedures, had a higher proportion of deaths declared in the field, and had more field trauma activations, as compared with children injured by other mechanisms (Table 1).

The population-adjusted annual incidence of children with gunshot injuries ranged from 1.9 to 30.9 per 100 000 by region (Fig 1A), a 16-fold difference. Older adolescents (age 15–19 years)

had a higher incidence of gunshot-related injuries than younger children at all sites. Compared with other injury mechanisms, gunshot injuries had the lowest incidence (7.5 per 100 000 children) (Fig 1B). When stratified by age group, the incidence of gunshot injuries differed more by age group than any other injury mechanism (24.9 per 100 000 older adolescents versus 1.7 per 100 000 younger children).

Among children transported by EMS with a matched hospital record available ($n = 11\,593$, 31.6% of all children transported to an acute care hospital), there were differences in injury severity and hospital interventions by mechanism of injury (Fig 2). Compared with other injury mechanisms, children with gunshot injuries had the highest proportion of ISS ≥ 16 (23.0%, 95% confidence interval [CI] 17.6–28.4). When assessed by body region, gunshot injuries caused the greatest proportion of AIS ≥ 3 abdominal/pelvic injuries (15.4%, 95% CI 10.0–19.9) and extremity injuries (13.9%, 95% CI 9.6–18.3). Serious head injuries were similar between children injured by gunshot (9.0%, 95% CI 5.3–12.7) and those struck by motor vehicles (9.1%, 95% CI 6.8–11.3). The proportion of AIS ≥ 3 chest injuries was similar between those with gunshot injuries (14.5%, 95% CI 10.1–19.0) and cut/pierce injuries (16.9%, 95% CI 13.0–20.8). There were also differences in hospital interventions by injury mechanism, with children having gunshot injuries incurring the greatest proportion of major surgical interventions (32.3%, 95% CI 26.1–38.5) and blood transfusions (9.1%, 95% CI 5.5–12.7). Children with gunshot injuries commonly required abdominal (20.5%, 95% CI 15.3–25.7), thoracic (8.5%, 95% CI 4.9–12.1), and vascular (7.1%, 95% CI 3.9–10.3) surgery.

Figure 3 compares in-hospital mortality and acute care costs by mechanism of

injury. In-hospital mortality for children with gunshot injuries (8.0%, 95% CI 4.7–11.4) was almost 4 times greater than the next highest group (cut/pierce, 2.2%, 95% CI 0.7–3.7). Among all 150 injured children who died ($n = 60$ declared in the field, $n = 90$ after transport), 32 (21%, 95% CI 15.1–28.8) died after gunshot injuries. The total number of injury deaths was exceeded only by motor vehicle occupant crashes ($n = 53$); however, in-hospital mortality for motor vehicle crashes (0.7%, 95% CI 0.5–1.0) was notably lower than for gunshot injuries. Total acute care costs followed a similar pattern, with children injured by gunshot incurring the highest average per-patient costs (\$28 510, 95% CI 22 193–34 827). The mechanism group with the next highest cost was struck by a motor vehicle (\$15 566, 95% CI 12 764–18 368).

Sensitivity analyses (in which missing hospital variables were imputed), including all children transported by EMS to an acute care hospital ($n = 36\,644$), demonstrated similar comparisons between children with gunshot injuries versus other injury mechanisms (Supplemental Figs 4 and 5). However, point estimates for hospital metrics were slightly lower across all mechanisms, reflecting the inclusion of injured children discharged from the ED after EMS transport for whom no hospital record was available for linkage.

DISCUSSION

In this study, we demonstrate that gunshot injuries in children are uncommon, but are associated with a disproportionate burden of adverse outcomes compared with other injury mechanisms. Gunshot injuries were more severe, requiring more frequent major therapeutic interventions and resulting in higher mortality and per-patient costs than any other injury mechanism. Although gunshot injuries accounted for only 1% of injured children, they were

associated with more than 20% of deaths after injury. The incidence of gunshot injuries also varied considerably between regions and age groups, with older adolescent males accounting for the majority of gunshot-related injuries.

Findings from this study are important for several reasons. There have been few population-based studies of children with gunshot injuries over the past decade. Similarly, gun research integrating the role of 9-1-1 emergency services has been limited. Our study involved both of these important elements. We demonstrate that one-third of children with an EMS response dying from gunshots are declared dead in the field and a substantive number are treated outside of major trauma centers, highlighting the limitations of previous research. Whereas previous studies have demonstrated the lethal nature of gunshot injuries in children,^{2–4,6–8,10,13–15} few have evaluated both out-of-hospital and in-hospital measures of injury severity, resource use, outcomes, and costs, compared with children injured by other mechanisms. These comparisons illustrate the immense per-patient impact of gunshot injuries in children. Even when compared with children injured by a cut/pierce mechanism (commonly grouped with gunshot injuries as “penetrating injury”), children with gunshot injuries were more severely injured and had notably higher mortality.

The frequency of gunshot injuries in children also differed widely by age group. Older adolescent males accounted for the majority of gunshot injuries and had substantially higher population-adjusted incidence rates compared with younger children. These findings suggest that injury prevention efforts to reduce gunshot injuries in children should begin at an early age, but focus particularly on older adolescent males. Gunshot-related injury is a major public health issue for children. The low

TABLE 1 Characteristics of Injured Children Served by EMS in 5 Regions

	Children Injured by Gunshots; <i>n</i> = 505 (1% of total)	Children Injured by Non-Gunshot Mechanisms; <i>n</i> = 49 478
Demographics (%)		
0–4 y	5 (1.0%)	7607 (15.4%)
5–9 y	16 (3.2%)	6789 (13.7%)
10–14 y	64 (12.6%)	10 799 (21.8%)
15–19 y	421 (83.2%)	24 283 (49.1%)
Male	427 (84.5%)	29 003 (58.6%)
Regions^a		
A	26 (5.2%)	3255 (6.6%)
B	78 (15.4%)	9675 (19.6%)
C	108 (21.4%)	10 587 (21.4%)
D	160 (31.7%)	17 857 (36.1%)
E	133 (26.3%)	8104 (16.4%)
Mechanism of injury (%)		
Gunshot	505 (100%)	—
Cut or pierce	—	1262 (2.6%)
Struck by blunt object	—	6224 (12.6%)
Fall	—	11 942 (24.1%)
Motor vehicle crash	—	14 357 (29.0%)
Pedestrian versus automobile	—	1737 (3.5%)
Other	—	13 956 (28.2%)
Out-of-hospital physiologic measures, procedures received, and triage status^b (%)		
Age-adjusted hypotension	58 (11.4%)	2388 (4.8%)
GCS score 13–15	448 (88.7%)	48 504 (98.0%)
GCS score 9–12	10 (2%)	571 (1.2%)
GCS score ≤8	47 (9.3%)	403 (0.8%)
Intubation attempt	44 (8.6%)	208 (0.4%)
Intravenous line placement	321 (63.5%)	9452 (19.1%)
Met ≥1 field trauma triage criteria	276 (54.7%)	7742 (15.7%)
Out-of-hospital disposition		
Death in the field	11 (2.2%)	49 (0.1%)
No transport	42 (8.2%)	12 500 (25.3%)
Transport by ground ambulance	451 (89.3%)	36 469 (73.7%)
Transport by helicopter	1 (0.2%)	223 (0.5%)
Transport by law enforcement	0 (0%)	236 (0.5%)
Type of hospital, among children transported to an acute care hospital (<i>n</i> = 36 644)^c		
Level I trauma center	330 (73.2%)	14 434 (39.9%)
Level II trauma center	66 (14.5%)	3396 (9.4%)
Non-trauma hospital	56 (12.3%)	18 362 (50.7%)

^a Raw counts of injured children by region; population-adjusted estimates are provided in Fig 1. Regions have been de-identified.

^b Hypotension was calculated as an initial out-of-hospital systolic blood pressure (mm Hg) $<70 + (2 \times \text{age in years})$.

^c The total number of children transported to an acute care hospital excludes children transported by EMS to clinics, urgent care clinics, and other non-hospital facilities (*n* = 500) and patients transported by law enforcement (*n* = 236). Hospital type represents the final destination hospital, including 790 (2.1%) children with inter-hospital transfer after initial EMS transport (17 children injured by gunshots).

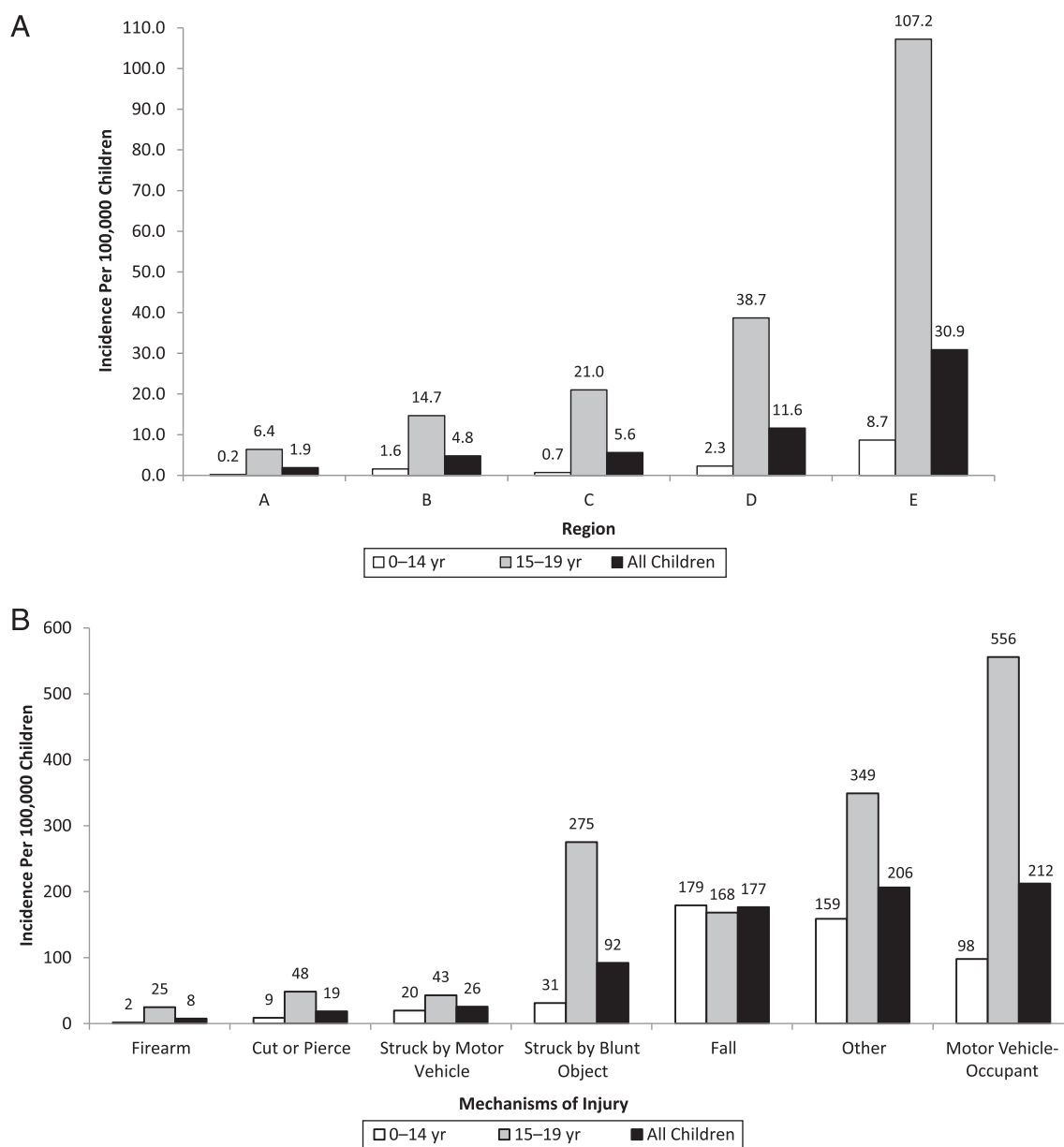
incidence and high burden of pediatric gunshot injuries suggests that more effective means to reduce such injuries must be strategic to have an impact. This pattern is in contrast to other injury mechanisms (eg, motor vehicle crashes) with high incidence and much lower per-patient injury burden. Lessons in improving child motor vehicle safety (eg,

booster seats,²⁹ age-appropriate restraint systems and seat position,^{30–32} air-bags^{33–36}) and the associated reductions in pediatric motor vehicle mortality³⁷ provide important examples of the potential impact of injury prevention efforts. The gains in motor vehicle safety required rigorous research to understand the problems, partnerships with

national organizations (eg, National Highway Traffic Safety Administration) and the automotive industry, and evidence-based legislation. Reducing gunshot injuries in children will likely require similarly broad-based, interdisciplinary efforts, in addition to rigorous research. Exploring the regional variation in pediatric gunshot injuries may also help direct injury prevention efforts, particularly in areas with disproportionately high rates of gunshot injuries among children.

We used a retrospective cohort study design, which can be limited by unmeasured confounding and bias. We attempted to minimize potential bias through population-based sampling from multiple EMS agencies, regions, and hospitals. Nevertheless, the robustness of our findings would be enhanced if replicated in larger prospective studies that include additional US cities. We attempted to maximize case ascertainment of injured children served by EMS and minimize bias in our incidence estimates through rigorous electronic data mechanisms^{18,19} and inclusion of EMS agencies with broad catchment areas. However, it is possible that some children with gunshot injuries did not have contact with EMS (eg, obvious death in the field without EMS involvement) or that certain children in our sample were non-residents of the geographic regions. Both of these factors could have affected our incidence estimates. Also, we did not have information about intent and therefore were unable to determine this important aspect of gunshot injuries to further delineate potential outcome differences.

Our estimates regarding the impact of gunshot-related injuries in children are conservative owing to several factors: (1) inclusion of children injured by powder-charged firearms and air guns in the “gunshot” category; (2) inclusion of children who died during hospitalization in the cost estimates, which could

**FIGURE 1**

Age- and population-adjusted annual incidence of injuries among children served by 9-1-1 EMS in 5 regions ($n = 49\,983$). A, Incidence of gunshot injuries in children, by region. B, Overall incidence of gunshot injuries versus other injury mechanisms.

have suppressed costs due to the high mortality rate; (3) lack of long-term outcomes and years of productive life lost to fully quantify the costs borne by society; (4) use of ISS, which can underestimate the severity of injury from penetrating trauma³⁸; and (5) lack of functional outcomes. Inclusion of these additional factors would further magnify the measurable impact of gunshot injuries in children. Also, our results do

not include the intense emotional impact and life changes incurred by surviving parents, family members, and affected communities after the death of a child.

Data were missing for a portion of important variables (eg, mechanism of injury). Rather than excluding patients with missing out-of-hospital values (complete case analysis), we used multiple imputation to handle missing

values, which has been shown to reduce bias³⁹⁻⁴⁴ and preserve the sampling design. Sensitivity analyses that included multiply imputed hospital values and different ways of coding patients' missing mechanism of injury yielded qualitatively similar findings.

Finally, the categories used for mechanism of injury were completed by EMS providers, rather than hospital-based data abstractors. Although mechanism

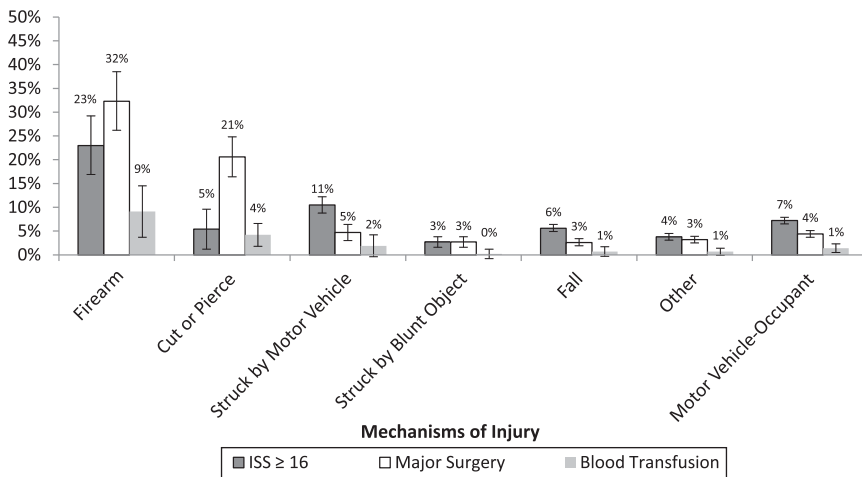


FIGURE 2 Injury severity and major hospital interventions among children transported by EMS with hospital information available ($n = 11\,593$).

of injury was completed using standardized categories by on-scene providers who evaluated the patient and injury setting, it is possible that the assigned categories could have differed if completed by trained hospital data abstractors. Also, the electronic health record for most participating EMS agencies had a single field for mechanism of injury and therefore did not allow

us to assess scenarios in which a patient may have had more than 1 injury mechanism.

CONCLUSIONS

We used a unique population-based cohort of injured children in 5 western US regions to demonstrate the disproportionate burden and adverse

outcomes associated with gunshot injuries compared with other pediatric injury mechanisms. Although the relative incidence of gunshot injuries is low, the impact is large, particularly among older adolescent males.

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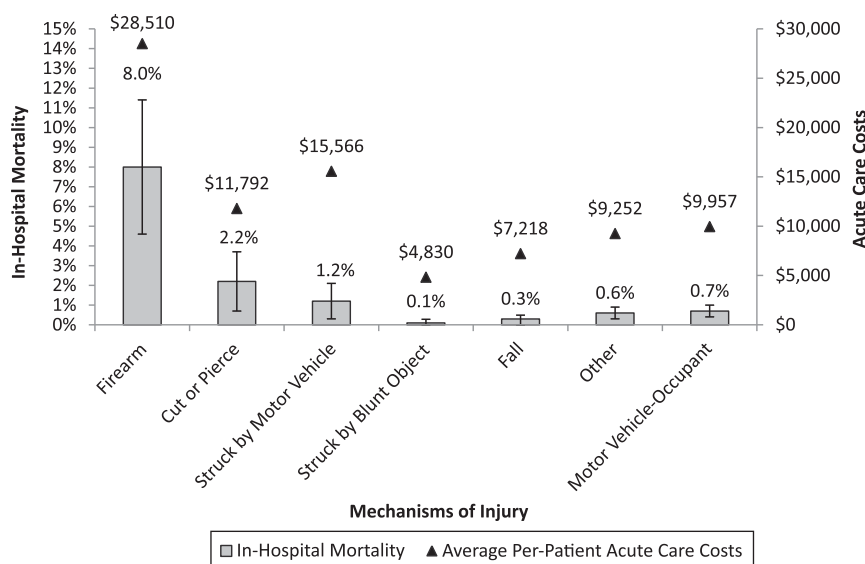


FIGURE 3 In-hospital mortality and total acute care costs among injured children transported by EMS with hospital information available ($n = 11\,593$). (Acute care costs include EMS [both scene transport and inter-hospital transport], ED, and in-hospital costs.) Nineteen percent of hospital costs were imputed by using multiple imputation owing to cost information being unavailable in matched ED records.

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