Injury, Int. J. Care Injured xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Injury

journal homepage: www.elsevier.com/locate/injury

Full length article

Gunshot wounds resulting in hospitalization in the United States: 2004–2013

Alan Cook[a,*], Turner Osler[b], David Hosmer[c], Laurent Glance[d], Frederick Rogers[e], Brian Gross[e], Pamela Garcia-Filion[f], Ajai Malhotra[g]

[a] Trauma Research Program, Chandler Regional Medical Center, 485 South Dobson Road, Suite 201, Chandler, AZ 85224, USA
[b] Department of Surgery, University of Vermont College of Medicine, 789 Orchard Shore Road, Colchester, VT 05446, USA
[c] Division of Biostatistics and Epidemiology, Department of Public Health School of Public Health and Health Sciences, University of Massachusetts,128 Worcester Road, Stowe, VT 05672, USA
[d] University of Rochester College of Medicine, 601 Elmwood Avenue, Rochester, NY 14642, USA
[e] Trauma and Acute Care Surgery, Lancaster General Hospital, 555 North Duke Street, Lancaster, PA 17602, USA
[f] University of Arizona College of Medicine-Phoenix, 591 East Linda Lane, Gilbert, AZ 85234, USA
[g] Department of Surgery, University of Vermont College of Medicine, 111 Colchester Avenue, Burlington, VT 05401, USA

ARTICLE INFO

Article history:
Accepted 26 January 2017

Keywords:
Firearms
Gunshot wounds
Violence
Suicide
Assault

ABSTRACT

Introduction: The United States (US) leads all high income countries in gunshot wound (GSW) deaths. However, as a result of two decades of reduced federal support, study of GSW has been largely neglected. In this paper we describe the current state of GSW hospitalizations in the US using population-based data.

Patients and methods: We conducted an observational study of patients hospitalized for GSW in the National (Nationwide) Inpatient Sample (NIS) 2004 –2013. Our primary outcome is mortality after admission and we model its associations with gender, race, age, intent, severity of injury and weapon type, as well as providing temporal trends in hospital charges.

Results: Each year approximately 30,000 patients are hospitalized for GSW, and 2500 die in hospital. Men are 9 times as likely to be hospitalized for GSW as women, but are less likely to die. Twice as many blacks are hospitalized for GSW as non-Hispanic whites. In-hospital mortality for blacks and non-Hispanic whites was similar when controlled for other factors. Most GSW (63%) are the result of assaults which overwhelmingly involve blacks; accidents are also common (23%) and more commonly involve non-Hispanic whites. Although suicide is much less common (8.3%), it accounts for 32% of all deaths; most of which are older non-Hispanic white males. Handguns are the most common weapon reported, and have the highest mortality rate (8.4%). During the study period, the annual rate of hospitalizations for GSW remained stable at 80 per 100,000 hospital admissions; median inflation-adjusted hospital charges have steadily increased by approximately 20% annually from $30,000 to $56,000 per hospitalization. The adjusted odds for mortality decreased over the study period. Although extensively reported, GSW inflicted by police and terrorists represent few hospitalizations and very few deaths.

Conclusions: The preponderance GSW hospitalizations resulting from assaults on young black males and suicides among older non-Hispanic white males have continued unabated over the last decade with escalating costs. As with other widespread threats to the public wellbeing, federally funded research is required if effective interventions are to be developed.

Introduction

The United States leads in gunshot wound (GSW) mortality among all high income nations [1]. Firearm-related injuries resulted in an estimated 385,769 emergency department visits and resulted in 141,914 hospital admission and cost $88.6 billion from 2006 to 2010 in the United States (US) [2]. The cost of GSW extends well beyond medical treatment alone. Total lifetime costs

* Corresponding author at: Chandler Regional Medical Center, 485 S Dobson Rd. Suite 201 Chandler, AZ, 85224, USA.
E-mail addresses: adcookmd@gmail.com (A. Cook), tosler@uvm.edu (T. Osler), hosmer@schoolph.umass.edu (D. Hosmer), laurent_glance@urmc.rochester.edu (L. Glance), frogers2@lghealth.org (F. Rogers), bgross2@lghealth.org (B. Gross), pam_ala@yahoo.com (P. Garcia-Filion), ajai.malhotra@uvmhealth.org (A. Malhotra).

http://dx.doi.org/10.1016/j.injury.2017.01.044
0020-1383/

for fatal and nonfatal GSW injuries sum to $44 billion and $1.4 billion, respectively [3]. Single year productivity losses due to GSW have been estimated greater than $35 billion [4]. Several investigators have noted annual GSW mortality rates of 28,000 −35,200 deaths in reports from 1993 to 2010 [2,3,5,6]. Previous work has shown high rates of hospitalized GSW patients are discharged with disabilities [7]. For example, GSWs are the third most frequent cause of traumatic spinal cord injury [8]. Until recently, legislation prohibiting research on GSW at the Centers for Disease Control and Prevention (CDC) and later the entire Department of Health and Human Services has slowed understanding of the health care implications of this signature American epidemic for the last two decades [9,10]. The lack of objective data requires public policy to be based upon opinion and ideology alone.

Over the years, some information concerning GSW has accrued [3,11–13]. Such reports include single institution studies [13] and analyses of vital statistics death registries and episode tracking systems like the National Electronic Injury Surveillance System [3]. One dataset which provides a population-based perspective of hospitalizations for GSW is the Healthcare Cost and Utilization Project (HCUP) National (Nationwide) Inpatient Sample (NIS). We describe the current, demographics, in-hospital mortality, and hospital charges for patients hospitalized following GSW in the US. The institutional review boards from Chandler Regional Medical Center and the University of Vermont approved this project.

Patients and methods

A descriptive epidemiological study was performed using data from the NIS for the ten years, 2004–2013. The NIS is an anonymized, stratified probability sample of clinical and hospital charge data abstracted from hospital billing data compiled by Agency for Healthcare Research and Quality (AHRQ) and HCUP and includes all patients covered by public and private insurers, as well as those who are uninsured [14]. The NIS database contains data from hospitalized patients only, thus excluding less severe injury, emergency department (ED) treat and release patients as well as fatally injured GSW patients who die prior to admission. Despite the exclusion of these two groups from the NIS, important insights can be gleaned about this middle group of patients, specifically their race, gender and age, intent, weapon type, as well as temporal trends of in-hospital mortality, and details about their hospital stays. and hospital charges.

Each year the NIS provides information on approximately 8 million inpatient stays from about 1000 hospitals. The sampling probabilities are proportional to the number of US community hospitals in each stratum. Community hospitals are defined as all non-Federal, short-term, general, and other specialty hospitals, excluding hospital units of institutions. Included among community hospitals are public hospitals and academic medical centers. This universe of U.S. community hospitals is divided into strata using five hospital characteristics: ownership/control, bed size, teaching status, urban/rural location, and U.S. region. Prior to 2012, the NIS included data from every hospital admission from a 20 percent sample of hospitals from “partner states”, that is, states that submit data to the HCUP [15], a group of between 37 and 46 states over the period of this study. Beginning in 2012, the NIS changed the sampling frame to 20 percent of discharges from all hospitals in the partner states. To facilitate the calculation of national estimates, trend weights and discharge weights are provided with TRENDWT for years prior to 2012 and DISCHWT data fields for the years 2012 and 2013. Each discharge weight represents the number of target universe discharges that each sampled discharge represents in its stratum.

The analysis included only patients admitted for treatment of injuries due to GSWs as identified by the 24 International Classification of Diseases, 9th Revision, Clinical Modification, (ICD-9) External Cause of Injury Codes (E-Codes) describing both the intent and the type of weapon used in firearm related injuries as follows: unintentional firearm deaths (E922.0–E922.9), suicide or self-inflicted firearm injury deaths (E955.0–E955.4), assault-related firearm injury (E965.0–E965.4), legal intervention injuries by firearm (E970), terrorism involving firearms (E979.4), firearm injuries of undetermined intent (E985.0–E985.4). The E-Codes also describe weapon type, categorized as handgun, shotgun, hunting rifle, military and other/unknown. Traumatic shock was defined as ICD-9 code 958.4 and was included as a measure of physiologic derangement.

Patient characteristics, including gender, age, severity of injury, race, comorbid conditions, GSW intent, gun type, insurance status, length of stay and yearly rates of GSW admissions were tabulated in total and by hospital discharge status. Anatomic injury severity was computed from injury related ICD-9 codes using the Trauma Mortality Prediction Model (TMPM) [16]. The TMPM estimates each patient’s probability of death based only on their recorded anatomic injuries. The TMPM better predicts mortality than does ISS, particularly when injuries are recorded in the ICD-9 lexicon [17]. The outcomes of interest were temporal trends of hospitalization, in-hospital mortality, length of hospital stay, and hospital charges from the TOTCHG data field in the NIS dataset. Payer information is categorized as commercial/HMO, Medicare/Medicaid, and uninsured, and trended annually.

Statistical analysis

The significance of temporal trends were tested using Spearman's rank correlation coefficients. Logistic regression was used to model factors that were associated with dying before hospital discharge. Predictors were selected using the method of purposeful selection, and continuous variables age and the logit transformation of the TMPM probability of death were modeled using second degree fractional polynomials as outlined by Hosmer, Lemeshow and Sturdivant [18]. Interactions among predictors were assessed and none were found to be significant. This logistic model was also used to examine the trend adjusted in-hospital mortality over time. The model’s ability to discriminate survivors from fatalities was evaluated by the area under the receiver operating characteristic curve (ROC) [19]. The Hosmer-Lemeshow goodness-of-fit test (H-L) assessed model calibration [20]. The H-L has been shown to be sensitive to large sample sizes [21]. Recently, a method of bootstrapping with iterative H-L tests have been shown to yield reliable estimates of goodness-of-fit for logistic regression models with large samples [22]. This process was done with ten samples of 5000 observations each to evaluate the goodness-of-fit for the logistic regression model.

Discharge and trend weights provided by AHRQ were used throughout to calculate national estimates for the outcomes of interest, but were not used in the construction of the mortality model; as a result standard errors for this model are somewhat inflated. The U.S. Bureau of Labor Statistics Consumer Price Index inflation calculator was employed to estimate the increase in median total hospital cost in constant 2015 dollars [23]. All data manipulation and statistical analysis was performed using Stata/MP, version 14.2.

Results

The NIS provided data on a total of over 385 million hospital admissions during the 10 year study period. This study was confined to the 292,595 (0.08%) patients who were admitted following GSW, a proportion that remained stable from year to year over the decade of study.

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GSW patients were overwhelmingly male (85.3%) and young (median age 26); black patients were substantially over represented (45.5%). GSWs were most commonly the result of assaults (61.2%), unintentional GSW (22.5%) or suicides (8.3%); assaults were especially common among young black males. Non-Hispanic whites had an average in-hospital mortality of 10.5%, which was higher than that of other races whose mortalities ranged from 5.4% (black) to 6.28% (Asian). In-hospital mortality among non-Hispanic whites accounted for 45.1% of the overall mortality of the cohort with suicide as the primary mechanism (31.1%). The category of "undetermined intent" is likely a mix of the other intent categories and may be proportional to the known mechanisms of intent. Although suicide attempts were less than 10% of admissions, 35.5% of deaths occurred because suicide was overall almost 7 times more deadly compared to assaults or unintentional GSW. Suicide was more common among older patients, and especially among older non-Hispanic white patients. (Fig. 1) The type of gun was unknown in 59.4% of cases, however when weaponry was known handguns dominated all other weapons (77.1%) and was the most lethal type of gun with an overall in-hospital mortality of 8.4%. (Table 1) For assault-related GSW hospital admissions, mortality by gun type was evenly distributed among handguns (4.5%), shotguns (4.5%), hunting rifles (5.3%), and military-style guns (4.1%).

Unadjusted in-hospital mortality ranged from 7.2% (95% CI 6.6–7.9) to 9.1% (8.4–9.8) but showed no significant trend over time ($p = 0.40$), see Appendix A Fig. A1. Police shootings accounted for few hospitalizations (1.8%) and 7.7% of deaths. Ten people were hospitalized due to terrorist GSW and all 10 survived. In-hospital mortality rates increased sharply with age in patients over the age of 50. Among this group of patients 50 years-old and older, the mortality climbed steeply from 10.6% to 46.4%, $p < 0.001$. One-fifth of the cohort hospitalized for GSW was younger than 20 years old, and of these children and young adults, 11.6% died. Comorbid conditions present on admission were not common. However, among patients with comorbid diseases, in-hospital mortality was highest among those with cancers (metastatic (23.5%), solid tumor without metastasis (21.3%), and lymphoma (16.4%)), depression (11.9%), and hypertension (10.7%) (Table 1).

As expected, the logistic model showed that greater degree of anatomic injury, older age, and the presence of traumatic shock to be strongly associated with death, as was the mechanism of self-inflicted GSW. After adjustment, black patients were no more likely to succumb to their injuries compared to non-Hispanic whites; all other races were slightly less likely to die than non-Hispanic whites. In general, income level was not associated with in-hospital mortality, although the highest income quartile was at a slight in-hospital survival disadvantage. Four groups of year with similar estimated coefficients emerged after examining the nine estimated coefficients for year using 2004 as the referent: 2004, 2005–2006, 2007–2010 and 2011–2013. A model using these four groups was fit and found to be not significantly different from the more complicated using year at 10 levels. In addition, estimated odds-ratios from the four group model fit are simpler to interpret for a clinical audience (Table 2) The mortality model had excellent discrimination (ROC = 0.94) and calibration computed using the approach suggested by Barkley[22] supported model fit (10 H-L tests range 3.80–17.34, $p = 0.03$–0.87).

Over the study period, median hospital LOS decreased by one day from 4 to 3 days ($p < 0.001$) and the median hospital charge in constant 2015 dollars more than doubled, from $24,027 to $54,836, (128% increase). During this period, the rates of patients with private insurance decreased slightly (1.8%) while coverage for Medicare and Medicaid increased by 5.2%. One-third of the cohort had no insurance (Fig. 2).

Discussion

Each year approximately 30,000 patients are hospitalized for GSW, and 2500 die in hospital. Men are nine times as likely to be hospitalized for GSW as women, but are less likely to die. Fifty-seven percent more blacks are hospitalized for GSW as non-Hispanic whites. In-hospital mortality for blacks and non-Hispanic whites was similar when controlled for other factors. Most GSW are the result of assaults, which overwhelmingly involve blacks; accidents are also common and more often involve non-Hispanic whites. Although suicide is much less common, it accounts for a third of all deaths; most of which are older non-Hispanic white males. Handguns are the most common weapon reported, and are associated the highest death rate by gun type. During the study period, the annual number of hospitalizations for GSW, and length of stay remained stable; charges have steadily increased by approximately 20% annually while the adjusted log odds for mortality decreased.

Our population-based estimates of annual hospitalizations for GSW in the United States are similar to those reported by Fowler, et al., [3] as well as the Web-based Injury Statistics Query and Reporting System (WISQARS) from the CDC [24]. While GSWs can be immediately fatal, the consequences of GSWs for victims who do not immediately die are also profound. Each year firearm violence results in nearly 2500 deaths prior to hospital discharge in the present study. It has been estimated when prehospital and hospital deaths from GSW are combined, more than 31,000 die annually [24]. Meanwhile, annual hospital charges for GSW have

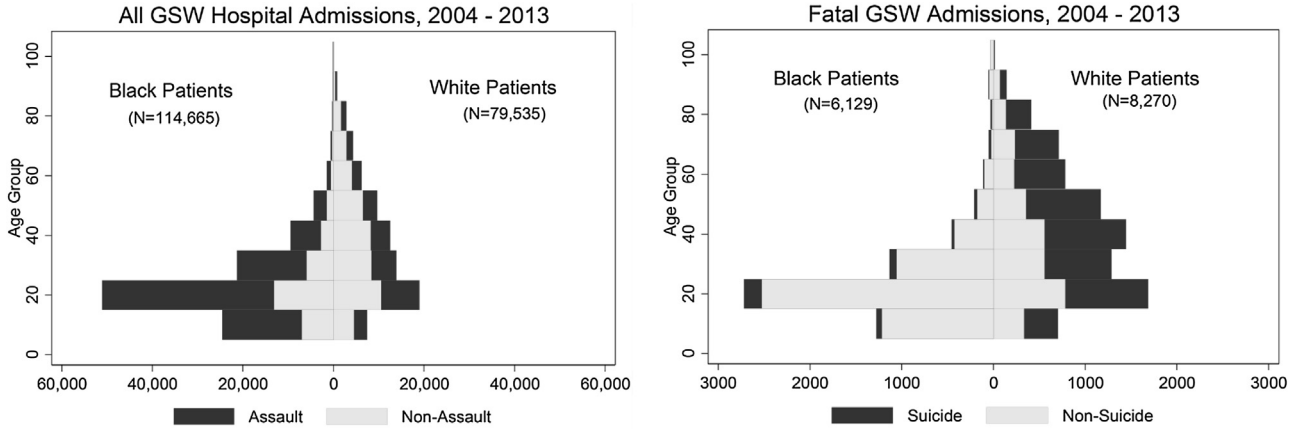

Fig. 1. Hospital GSW assault and suicide admissions by age and Black/White race.

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Table 1
Characteristics of patients admitted for GSW 2004–2013.

	All, n (%)		Lived, n (%)		Died, n (%)	
Sex, Male	259,650	(89.4)	238,115	(91.9)	21,100	(8.1)
Female	30,787	(10.6)	27,854	(90.6)	2905	(9.5)
Age groups: 10–19	56,084	(19.4)	52,509	(93.8)	3490	(6.2)
20–29	116,020	(40.1)	107,870	(93.1)	8007	(6.9)
30–39	56,454	(19.5)	52,179	(92.6)	4154	(7.4)
40–49	31,633	(10.9)	28,675	(90.8)	2915	(9.2)
50–59	19,706	(5.8)	14,503	(87.0)	2171	(13.0)
60–69	7011	(2.4)	5779	(82.5)	1227	(17.5)
70–79	3265	(1.1)	2356	(72.2)	909	(27.8)
80–89	1525	(0.5)	962	(63.1)	563	(36.9)
90–99	436	(0.2)	198	(45.3)	239	(54.7)
100+	347	(0.1)	183	(53.4)	160	(46.6)
Race/Ethnicity: Black	119,319	(49.1)	103,860	(94.6)	5923	(5.4)
Non-Hispanic White	67,775	(27.9)	68,127	(89.5)	8013	(10.5)
Hispanic	43,210	(17.8)	39,316	(93.5)	2737	(6.5)
Asian	2529	(1.0)	2861	(93.9)	188	(6.2)
Native American/Alaska Native	1735	(0.7)	1547	(93.2)	114	(6.8)
Other	8681	(3.6	7700	(90.6)	803	(9.4)
Comorbid Conditions						
Hypertension, Uncomplicated and Complicated	35,142	(12.1)	32,537	(92.6)	2605	(7.4)
Drug Abuse	33,869	(11.6)	33,053	(97.6)	816	(2.4)
Alcohol Abuse	27,399	(9.4)	26,441	(96.5)	958	(3.5)
Chronic Lung Disease	19,752	(6.8)	18,761	(95.0)	991	(5.0)
Deficiency Anemia	14,199	(4.9)	13,258	(93.4)	942	(6.6)
Depression	12,842	(4.4)	11,301	(88.0)	1541	(12.0)
Psychoses	11,741	(4.0)	11,187	(95.3)	555	(4.7)
Liver Disease	2068	(0.7)	1828	(88.4)	241	(11.6)
Solid Tumor Without Metastasis	989	(0.3)	783	(79.2)	206	(20.8)
Metastatic Cancer	653	(0.2)	505	(77.3)	149	(22.7)
Lymphoma	296	(0.1)	248	(83.8)	48	(16.2)
Intent: Assaults	179,793	(61.5)	169,687	(94.5)	9902	(5.5)
Unintentional	65,502	(22.4)	62,399	(95.4)	3034	(4.6)
Suicide	24,624	(8.4)	15,924	(64.8)	8648	(35.25)
Undetermined	17,401	(6.0)	15,226	(87.6)	2152	(12.4)
Law enforcement	5266	(1.8)	4780	(92.3)	399	(7.7)
Terrorism	10	(<0.01)	10	(<0.01)	0	
Gun Type: Other/Unknown	173,291	(59.2)	158,910	(91.9)	14,080	(8.1)
Handgun	92,144	(31.5)	83,657	(90.9)	8379	(9.1)
Shotgun	20,686	(7.1)	19,429	(94.0)	1233	(6.0)
Hunting Rifle	5691	(1.9)	5274	(92.8)	413	(7.3)
Military	785	(0.3)	756	(96.3)	29	(3.7)
TMPM[a] probability of death, median (IQR)	0.019	(0.05)	0.017	(0.03)	0.329	(0.52)
Insured	160,284	(61.9)	146,674	(91.6)	13,444	(8.4)
Length of stay, median days, (IQR)	4	(7)	4	(6)	1	(2)
Year: 2004	31,644	(10.8)	28,767	(90.9)	2873	(9.1)
2005	29,138	(10.0)	27,030	(92.8)	2085	(7.6)
2006	29,449	(10.1)	27.79	(92.0)	2341	(8.0)
2007	30,227	(10.3)	27,760	(91.9)	2434	(8.1)
2008	26,119	(8.9)	24,084	(92.2)	2035	(7.8)
2009	27,099	(9.3)	24,755	(91.6)	2280	(8.4)
2010	36,883	(12.6)	33,397	(90.9)	3358	(9.1)
2011	27,161	(9.3)	24,900	(92.0)	2180	(8.1)
2012	28,106	(9.6)	25,721	(91.6)	2346	(8.4)
2013	26,775	(9.2)	24,535	(91.8)	2205	(8.3)
Died	24,133	(8.3)				

[a] Trauma Mortality Prediction Model.

grown to nearly $3 billion, a cost that does not include professional fees, lost income, lost tax revenue, or the human cost in pain, disability, and bereavement. When medical cost and work loss costs are combined, the annual burden exceeds $48 billion [3].

An unexpected finding was that the adjusted average in-hospital mortality for patients admitted to hospitals following GSW injury has decreased over the last decade by 40%. This may be the result of better trauma systems, including advances in care from emergency medical services and the acute care surgical management of GSW patients once they arrive at the ED. Although some reports from individual centers have found an increase in in-hospital mortality during an overlapping time frame [13], an in depth evaluation of trauma systems and practice patterns is beyond the scope of this study. Because the rate of GSW admissions has not changed, this decrease in GSW in-hospital mortality has had the apparent effect of decreasing the overall number of

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Table 2
Predictors of hospital mortality in patients admitted for GSW 2004–2013.[a]

	Odds Ratio[a]	95% Confidence Interval	P-value
Sex, Male	1.22	1.06–1.40	0.005
GSW Intent, Reference: Unintentional			
Suicide	3.69	3.15–4.32	<0.001
Assaults	0.91	0.80–1.04	0.16
Other/Undetermined	1.72	1.44–2.06	<0.001
Year, Reference: 2004			
2005–2006	0.83	0.70–0.99	0.04
2007–2010	0.81	0.69–0.94	0.006
2011–2013	0.61	0.52–0.72	<0.001
Race/Ethnicity, Reference: non-Hispanic White			
Black	0.99	0.88–1.12	0.93
Hispanic	0.89	0.77–1.03	0.13
Asian	0.58	0.36–0.94	0.03
Native American/Alaska Native	0.58	0.30–1.10	0.10
Other	1.44	1.14–1.80	0.002
Zip Code Income Quartile, Reference: Highest			
2	0.98	0.88–1.09	0.71
3	1.03	0.91–1.17	0.67
4	1.07	0.91–1.26	0.40
Shock	3.01	2.67–3.39	<0.001

[a]Adjusted for age and severity of injury, included but coefficients not shown, using the following fractional polynomial transformation.
Age1 = AGE Age2 = AGE·ln(AGE).
TMPM1 = TMPM^3 TMPM2=*X*3·ln(TMPM).
OR: using the (1,1) for Age and (3,3) for TMPM.

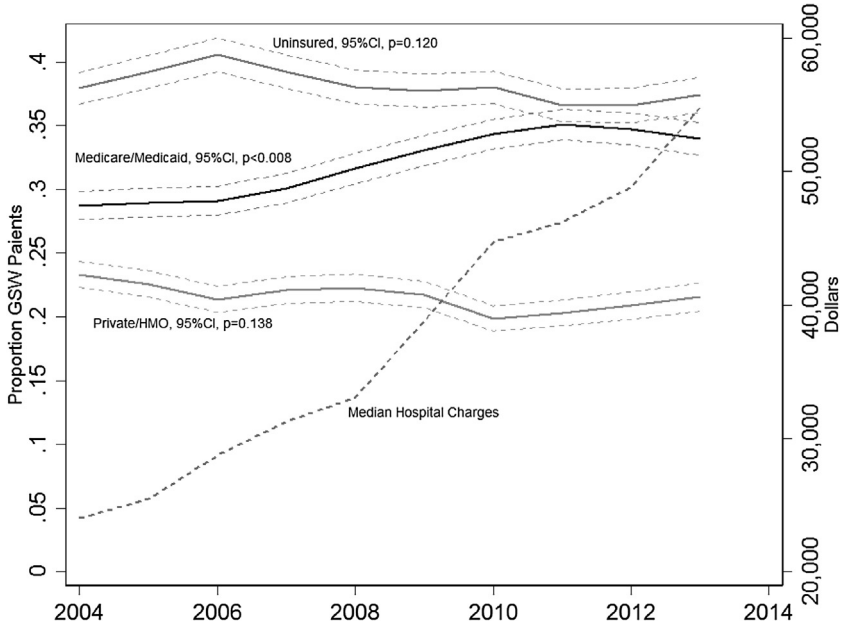

Fig. 2. Payer mix for GSW patients 2004–2013.

"homicides", that is, assault-related GSW that result in death. It is likely that such improvements are, at least, in part due to the efforts of frontline health care providers, though other reasons have been suggested by pundits, politicians and police commissioners [25–37].

The continuing burden of GSWs can be thought of as the tragic confluence of two distinct phenomena linked only by the coincidence of having guns as their common mechanism: the first is an epidemic of assaults upon young black men, the second an epidemic of suicides among older non-Hispanic white men. Other investigators have observed a similar association of suicide by firearm among middle-aged non-Hispanic white men, persons with cancer, and chronic illnesses like end-stage renal disease [38–42]. Because these phenomena are quite different, distinct policy initiatives will be required to combat them. Thus, while expanded psychiatric and hospice care may mitigate the self-inflicted gun violence found in older males, an entirely different approach will be required to address the epidemic of GSW that are the result of assaults on young, largely black, men. In fact, Wintemute observed that GSW was the leading cause of death for black males, ages 15–34 [43]. However, because guns, and handguns in particular, are involved in both epidemics, initiatives

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aimed at handguns are an obvious starting point. Specific policy proposals are the province of our legislators, but, because the very high cost of treating gunshot wounds is unlikely to decrease, policies aimed at preventing GSWs are an economic necessity.

Citizens reasonably look to their governments for remedy when the public welfare is threatened. In matters of healthcare, federal agencies like the National Institutes of Health and the CDC are charged with understanding and combating epidemics. For example, in 2004 US federal funding for domestic and international HIV/AIDS research was estimated to total $3 billion [44]. However, beginning in 1997 congress has discouraged research into GSW. The Omnibus Consolidated Appropriations Act of 1997 explicitly stated, " . . . none of the funds made available for injury prevention and control at the CDC may be used to advocate or promote gun control [9]." Research into the epidemic of GSW was further impeded by the Consolidated Appropriations Act of 2012 which further banned firearm-related medical research throughout the entire U.S. Departments of Health and Human Services, Labor and Education by prohibition of the use of funds for the " . . . advocacy or promotion of gun control [10]." In the absence of such funding, prospective prevention initiatives are unlikely to be developed and studied.

Based upon the results of this study, one can conservatively estimate over 500,000 people have been hospitalized due to GSW injuries and approximately 45,000 have died since the ratification of the Omnibus Consolidated Appropriations Act of 1997 at a cost of more than $45 billion in 2015 dollars. In January of 2013, President Barack Obama issued a memorandum calling for the Department of Health and Human Services, through the CDC to " . . . conduct or sponsor research into the causes of gun violence and the ways to prevent it [45]." However, no government appropriations or reversal of the ban on federal funding of firearm research has occurred. Like most GSW studies in the literature, the present study was investigator funded.

A notable strength of this study is the population-based nature of the dataset that allows for inferences that are more generalizable than those from single institutions. This study has limitations. First, although the NIS samples all hospital admissions, it is an administrative, not clinical, database. Like other studies of administrative data, ours is subject to the same problemss, including variation in diagnosis accuracy and data completeness. A second limitation is the inability to identify the number of times a patient was shot from the NIS dataset, because it is known that multiple GSW increase mortality [13,46]. However, use of the TMPM captured all injuries, so the addition of number of GSW is unlikely to affect the study's conclusions.

Conclusions

Tens of thousands of injuries, hospital admissions, and deaths, combined with the billions of healthcare dollars spent are the annual toll of GSW in the United States. The twin epidemics of GSW assaults on young black men and GSW suicides by older non-Hispanic white men persisted over the decade of this study, suggesting that multiple strategies will be required to address this public health crisis. Every epidemic requires that a government fund the research required to protect its citizens; the epidemic of GSW injury and death is no different.

Conflict of interest

All authors declare that they have no real or potential conflicts of interest regarding the conduct or findings of this study.

Appendix A.

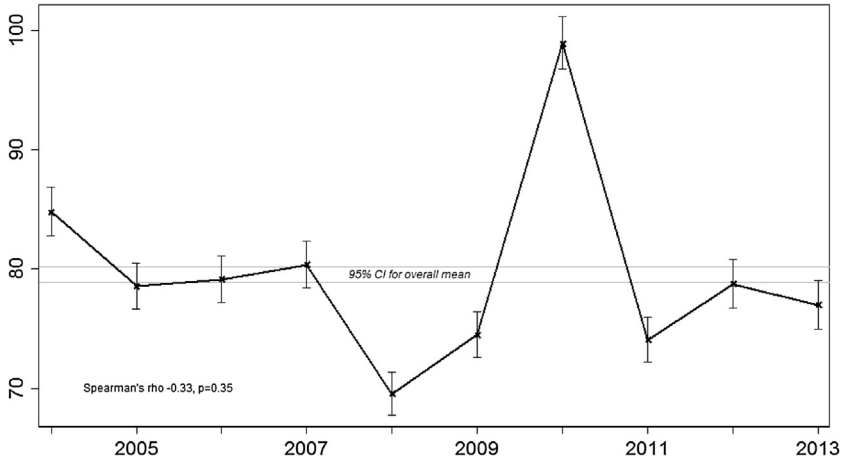

Fig. A1. GSWs per 100,000 admits per year.

Please cite this article in press as: A. Cook, et al., Gunshot wounds resulting in hospitalization in the United States: 2004–2013, Injury (2017), http://dx.doi.org/10.1016/j.injury.2017.01.044

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Please cite this article in press as: A. Cook, et al., Gunshot wounds resulting in hospitalization in the United States: 2004–2013, Injury (2017), http://dx.doi.org/10.1016/j.injury.2017.01.044