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BACKGROUND AND OBJECTIVES: Firearm-related traumatic brain injury (TBI) has emerged as a significant public health issue in the United States, coinciding with a rapid increase in gun-related deaths. This scoping review aims to update our understanding of firearm-related TBI in adult populations.

METHODS: A comprehensive search of 6 online databases yielded 22 studies that met the inclusion criteria. The reviewed studies predominantly focused on young adult men who were victims of assault, although other vulnerable populations were also affected.

RESULTS: Key factors in evaluating patients with firearm-related TBI included low Glasgow Coma Scale scores, central nervous system involvement, hypotension, and coagulopathies at presentation. Poor outcomes in firearm-related TBIs were influenced by various factors, including the location and trajectory of the gunshot wound, hypercoagulability, hemodynamic instability, insurance status, and specific clinical findings at hospital admission.

CONCLUSION: Proposed interventions aimed to reduce the incidence and mortality of penetrating TBIs, including medical interventions such as coagulopathy reversal and changes to prehospital stabilization procedures. However, further research is needed to demonstrate the effectiveness of these interventions. The findings of this scoping review hope to inform future policy research, advocacy efforts, and the training of neurosurgeons and other treating clinicians in the management of firearm-related TBI.

KEY WORDS: Firearm, Gunshot wound, Gun violence, Head injury, Traumatic brain injury

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In 2021, the Centers for Disease Control and Prevention reported a record-high of 48 830 gun-related deaths in the United States.[1] This marked a 14% increase from the previous year, a 25% surge compared with 5 years prior, and a 43% increase compared with a decade earlier.[2] Of particular concern are the severe traumatic head injuries resulting from firearm incidents, which pose significant risks to morbidity and mortality.[3] Cranial gunshot wounds (GSWs) have a reported survival rate of 10%–15% and often lead to highly morbid traumatic brain injuries (TBIs). These injuries occur due to various reasons, including assault, suicide, encounters with law enforcement, or accidental discharge.

ABBREVIATIONS: CNS, central nervous system; **GSW,** gunshot wound; **IPV,** interpersonal violence; **ISS,** injury severity score; **LOS,** length of stay; **NSP,** National Sample Program; **NTDB,** National Trauma Data Bank; **PRISMA,** Preferred Reporting Items for Systematic Reviews and Meta-Analyses; **SMR,** spinal motion restriction; **TBI,** traumatic brain injury.

TBI remains a major contributor to death and disability in the United States, with over 64 000 TBI-related deaths recorded in 2020.[4] Firearm suicide accounts for nearly half (48.3%) of the observed increase in TBI-related deaths from 2008 to 2017, surpassing falls, motor vehicle crashes, and assaults. Racial and ethnic minorities, service members and veterans, survivors of intimate partner violence (IPV), and individuals residing in rural areas bear a disproportionate burden of these injuries.[4] Furthermore, the COVID-19 pandemic exacerbated the prevalence of gun-related assaults and TBIs,[5,6] with a significant surge in firearm acquisitions and a subsequent rise in suicide and homicide rates.[7-9] This surge in gun violence, particularly among the youth,[10] highlights the urgent need to update our understanding of firearm-related TBI epidemiology, presentation, and management.

We conducted a structured scoping review of the literature focusing on adults in the United States. The objectives of the review were to (1) characterize the epidemiology of adult firearm-related TBI, (2) summarize significant outcomes and

complications, (3) identify prognostic factors, and (4) highlight proposed actions for reducing morbidity and mortality. Through this review, we aim to provide an overview of the concepts and contexts surrounding adult firearm-related TBIs in the United States and offer insights for future investigations and policy.

METHODS

Search Strategy

We conducted a scoping review in collaboration with a trained medical library scientist (L.O.). An original search strategy was developed for the Ovid MEDLINE database, focusing on 4 main concepts: (1) adults, (2) firearms, (3) head trauma, and (4) the United States. Medical subject headings terms and relevant keywords were used, searching the title, abstract, and keyword fields. No filters or limiters were applied. The review was completed by June 2022. Six databases were included: Ovid MEDLINE, Embase, Web of Science, CINAHL, PsychINFO, and the Cochrane Library. The final search results were imported into a citation manager and deduplicated.

Data Availability Statement

The complete original search strategy is available on request. All other data associated with this manuscript are provided herein. As this study involved the review of published data without experimentation on human or animal subjects, it is exempt from ethics board review. This study was not registered in a systematic reviews database.

Eligibility Criteria

English language articles focusing on United States populations reporting original empirical research on the incidence or epidemiology of firearm-related TBI in adult patients (older than 18 years) were included. Studies conducted outside of the United States, on military operations, or involving pediatric patients were excluded. In addition, book chapters, review articles, abstracts, case studies, opinion/perspective pieces, and professional society statements were excluded. A critical appraisal was not performed as part of this scoping review.

Study Selection

Citation information and abstracts were managed using Rayyan, a web-based citation manager.[11] Two reviewers (G.R. and R.G.) established eligibility criteria, and 1 reviewer (G.R.) independently reviewed titles and abstracts for inclusion. Additional studies identified during the primary search were included if appropriate. Data extraction was conducted using a standardized chart, capturing study details such as setting, database used, year span, sample size, sex distribution, firearm types, mechanism of injury, overall mortality rates, and other relevant factors. The primary reviewer (G.R.) collected and verified all data, with subsequent verification by the secondary reviewer (R.G.). The data points were then tabulated and synthesized.

RESULTS

Sample Characteristics

Our search strategy yielded 871 articles from 6 databases. After removing duplicates, we screened 565 citations based on title and abstract, identifying 109 potentially eligible articles. After full-text review, 22 citations met the inclusion criteria. A Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow diagram in the Figure illustrates the sources and exclusion criteria, while Table 1 presents the statistical data from the included citations. Prognostic factors and proposed mitigation actions are summarized in Table 2.

Eighteen of the 22 articles reported data from 2000 to the present, while 4 articles had data spanning periods between 1989 and 2014. The included studies varied in scope, ranging from individual health center evaluations to analyses of national databases. Each study focused on specific epidemiological or demographic factors, resulting in considerable variability in the population sizes they examined.

Patient Demographics

In accordance with our primary objective to characterize the epidemiology of adult firearm-related TBI, we analyzed data from 22 included studies, collectively comprising 796 980 patients. The mean age of patients across the studies ranged from 25 to 64 years, with most studies reporting a mean age in the early 30s. Men accounted for a predominant majority, ranging from 59.7% to 93.33%. Fatality rates varied from 3.3% to 100%, with higher rates observed in studies focusing on self-inflicted injuries. Common weapon types included handguns (46.98%), air guns (32.77%), rifles (10.14%), and shotguns (9.52%). However, these proportions may vary across regions and populations studied. Differences in study objectives, data sources, and reporting biases may contribute to discrepancies in the representation of certain demographic groups. African Americans accounted for 48.47% of the studied populations, Caucasians 49.1%, and Hispanics 2.46%. The underrepresentation of suicides, a significant proportion of gun-related deaths, may affect the generalizability of injury mechanisms such as assault, self-inflicted, and unintentional. A small but significant percentage of firearm-related TBIs was attributed to recreational hunting hazards; the head and neck account for nearly half of the GSW injuries seen in hunters, mostly inflicted by rifles.[12]

One study using data from the National Trauma Data Bank highlighted regional patterns in the distribution of firearm-related TBIs.[3] Cases were most prevalent in the South (39.5%), followed by the West (19.7%), Midwest (16%), Northeast (4.8%), and unknown origin cases (19.9%). Mechanisms of injury also varied across regions, with self-inflicted injuries predominant in the Midwest and South, while assaults were more prevalent in the Northeast and West.[3]

Our review identified vulnerable populations, including the elderly and women experiencing IPV. The elderly had a higher suicide fatality rate, potentially influenced by factors such as frailty, isolated living conditions, and poor neuropsychiatric health.[13] Women facing IPV were at significantly higher risk of fatality when abusers had access to firearms and IPV assaults involving firearms were more likely to result in death compared with other weapons or physical force.[14] In addition, the use of

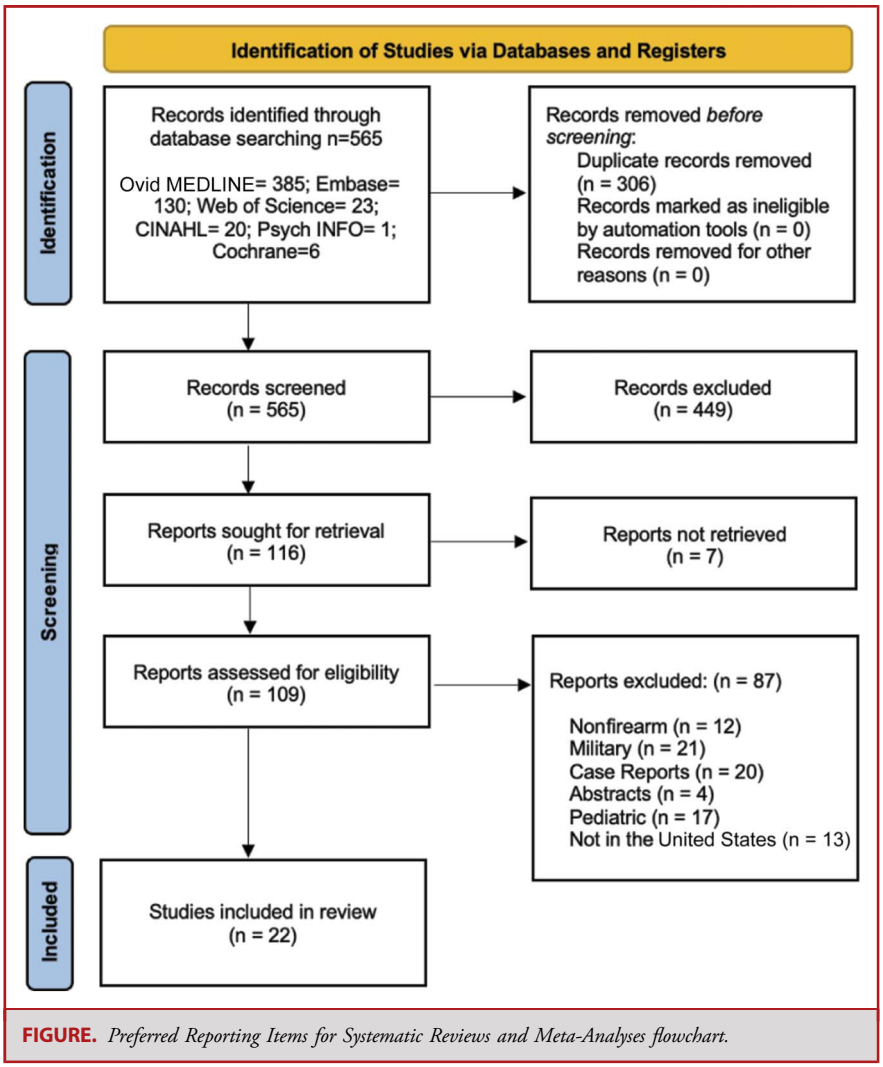

FIGURE. *Preferred Reporting Items for Systematic Reviews and Meta-Analyses flowchart.*

firearms in interpersonal homicides was associated with an increased incidence of multiple victimization in domestic homicides.[15]

Factors Affecting Health Outcomes in Adult Firearm-Related Patients With TBI

Medical Prognostic Factors

Building on our third objective to delineate prognostic factors for adult firearm-related TBIs, our findings emphasize several medical and radiographic indicators that influence patient outcomes. Prognostic factors for poor outcomes in adult patients with firearm-related TBIs included a Glasgow Coma Scale (GCS) score <9 and significant central nervous system (CNS) involvement, which correlated with a mortality rate of approximately 70%.[16,17] Other predictors of negative outcomes were higher injury severity scores, hypotension on admission, and longer length of stay (LOS).[3] Surprisingly, patients with positive toxicology screens at admission had higher survival rates compared with those with negative screens.[17] However, the relationship between blood alcohol content and overall survival remains controversial, with recent studies not finding a significant association.[18]

Radiographically, basal cistern effacement was associated with a 3.5 times higher likelihood of concomitant coagulopathy.[19] Coagulopathies, such as hypercoagulable hemostatic disturbances, have been linked to increased mortality in cranial GSW patients.[19] The missile trajectory of the GSW also influenced survival rates, with temporal GSWs having the highest mortality rate (82%).[16] Self-inflicted GSWs to the head and neck, specifically submental or intraoral trajectories, resulted in serious but survivable TBIs. Cerebral injury, particularly frontal lobe injury, also led to serious but survivable TBIs. Coronal trajectories were more frequently fatal compared with sagittal trajectories.[16,20,21]

Social Prognostic Factors

Social factors influencing mortality in cranial GSW cases included insurance status and geographic location. Uninsured patients had a 5-fold higher mortality rate than insured patients.[17]

TABLE 1. Article Study Characteristics Selected Through PRISMA Guidelines for Inclusion

Article #	Author	Setting/database	Gun-related injuries	Overall mortality	Percent men	Firearms used	Method of injury
1	Deng et al,[3] 2019	NSP of NTDB (2003-2012)	8148	54.60%	86.5%	Handgun (50.3%), other/unspecified (43.4%), shotgun (4.1), and hunting rifle (2.5%)	Assault (49.2%), self-inflicted (41.9%), and accident (3.5%)
2	Efron et al,[33] 2006	Urban Level 1 Trauma Center (2000-2005)	2949	3.30%	68.0%	N/A	N/A
3	McNickle et al,[36] 2020	Level 1 Trauma Center (2013-2017) and NTDB (2012-2016)	241	57%	85.0%	N/A	Self-inflicted (66%)
4	Finlay-Morreale et al,[43] 2009	Hamilton County Coroner (1998-2006)	115	44%	0.00%	N/A	Assault (100%)
5	Mansour et al,[19] 2021	Level 1 Trauma Center in Chicago, Illinois (2018-2020)	89	N/A	83.0%	N/A	Assault (83%), self-inflicted (9%), and accidental (8%); isolated PBI (85%) and polytrauma (15%)
6	Wertheimer et al,[45] 2008	Level 1 Trauma Center (2008)	45	N/A	82.0%	N/A	N/A
7	Yang et al,[5] 2022	Level 1 Trauma Center (2019-2020)	90	37.5%, unknown (12.5%)	93.3%	N/A	Assault (58.9%), self-inflicted (17.8%), and accidental (18.9%)
8	Murphy et al,[16] 2016	Tertiary Care Trauma Center (2002-2012)	157	59.9%	86.6%	N/A	Self-inflicted (100%)
9	Chopra et al,[38] 2018	Level 1 Trauma Center (2000-2016)	915	N/A	83.0%	Handgun (46%), air gun (31%), and shotgun (23%)	Assault (64%), accidents (29%), and self-inflicted (7%)
10	Lustenberger et al,[46] 2011	NTDB (2002-2006)	972	37.40%	86.4%	N/A	Assault (39.5%) Accidental (14.5%) Self-inflicted (39.8%)
11	Chiu et al,[23] 2019	National Inpatient Sample (2012-2016)	333	N/A	82.6%	N/A	N/A
12	Molina et al,[24] 2013	Bexar County Medical Examiner's Office (2000-2010)	1450	100%	83.1%	Handgun (100%)	Assault (45%) and self-inflicted (55%)
13	Kercher et al,[44] 2013	Law Enforcement Officers Killed and Assaulted (1996-2010)	61	100%	95.0%	Short-barrel (48%) and long barrel (46%)	Assault (100%)
14	Algattas et al,[6] 2021	Pennsylvania Trauma Systems Foundation (2020)	131	7.05%	59.0%	N/A	Assault (7.4%) and self-inflicted (1.1%)
15	Loder & Farren,[12] 2014	Inter-University Consortium for Political and Social Research Firearm Injury Surveillance Study (1993-2008)	543 505	5.90%	88.3%	Handgun (27.6%), rifle (6.1%), shotgun (5.7%), and air gun (19.7%)	Assault (59.4%), accident (33.6%), and self-inflicted (5.8%)
16	Schellenberg et al,[31] 2022	NTDB (2016-2017)	383	N/A	81.0%	N/A	Assault (79%), self-inflicted (9%), and accident (7%)

TABLE 1. Continued.

Article #	Author	Setting/database	Gun-related injuries	Overall mortality	Percent men	Firearms used	Method of injury
17	Graves et al,[34] 2021	NTDB (2008-2014)	27 121	18.80%	64.3%	N/A	N/A
18	Aarabi et al,[35] 2014	Office of Chief Medical Examiner in Baltimore (2000-2002)	786	91.0%	84.1%	N/A	N/A
19	Crutcher et al,[17] 2016	Office of Chief Medical Examiner in Baltimore (2008-2013)	111	42.3%	87.4%	N/A	Assault (56.8%) and self-inflicted (35.1%)
20	Quenzer et al,[25] 2021	NTDB (2012-2013)	4799	59%	84.3%	Handguns (65.7%) and other (34.3%)	Self-inflicted (100%)
21	Coronado et al,[64] 2011	CDC multiple-cause-of death (1997-2007)	203 126	100%	85.7%	N/A	Self-inflicted (74.2%), assault (22.2%), and accident (3.6%)
22	Richmond & Lemaire,[32] 2008	Federally Funded Surveillance System (2006-2008)	1453	0%	80.9%	N/A	Assault (57.8%) and self-inflicted (42.2%)

CDC, Centers for Disease Control and Prevention; N/A, not available; NSP, National Sample Program; NTDB, National Trauma Data Bank; PBI, penetrating brain injury; PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

Among insured patients, those with Medicare/Medicaid insurance had longer hospital stays and lower rates of returning home than those with private/commercial insurance.[3] Insurance status strongly affected accessibility to postacute care, with patients with uninsured TBI half as likely to be discharged to rehabilitation compared with insured patients.[22] Racial differences did not show significant variations in mortality, LOS, or surgical intervention among racial groups in cranial GSW cases.[17,23] However, the mechanism of injury played a significant role, with self-inflicted injuries associated with contact wounds to the head and the lowest rates of returning home compared with accidental injuries.[3,24,25] Similarly, geographic location was associated with a significant difference in morbidities. Geographic location also influenced morbidity patterns, with patients in the Southern United States experiencing longer hospital stays and higher odds of complications, including pneumonia, acute respiratory distress syndrome, cardiac arrest, and deep venous thrombosis.[3] Cranial GSWs in the Western United States had the lowest odds of these complications.[3] Finally, victims of civilian public mass shootings were twice as likely to have a head injury compared with victims of urban shootings.[26]

Efficacies of Guidelines and Aggressive Management for Cranial GSWs

The Brain Trauma Foundation's clinical and surgical management guidelines recommend aggressive management strategies for TBI in cranial GSW patients.[27,28] Implementation of these strategies has shown promising results, including a reported 55% survival rate at discharge in one center after adopting aggressive management.[29] Another center observed improved survival rates (from 10% in 2008 to 46% in 2011) after the use of aggressive management techniques such as resuscitation with blood products, hyperosmolar therapy, and administration of prothrombin complex concentrate.[30] Coagulopathy, characterized by platelet dysfunction, endothelial activation, disturbed fibrinolysis, endogenous anticoagulation, and inflammation, has been identified as a negative prognostic factor in cranial GSW patients.[19] However, the effects of coagulopathy reversal at 24 hours did not show a statistically significant improvement in outcomes in 1 study.[19]

Surgical interventions for firearm-related TBIs were explored, and tracheostomy performed within 24 hours of admission was associated with improved survival in patients with self-inflicted submental or intraoral GSWs, likely due to less severe CNS injuries compared with temporal or frontal trajectories.[16,24] Penetrating injuries to the vertebral artery were rare in firearm-related injuries (<1%) and were managed nonsurgically in 86% of cases.[31]

Mortality, Hospitalization, and Complications in Firearm-Related TBI

Firearm-related TBI result imposes significant morbidity and mortality burdens.[32] Mortality rates from penetrating head trauma accounted for 82.6% of all trauma deaths at 1 center.[33] However, in-hospital mortality is decreasing while prehospital mortality persists.[34] One possible contributing factor to the high mortality rate is the frequent occurrence of intracranial hematomas and intraventricular hemorrhage on presentation, leading to rapid brain damage or death.[35] Surviving patients often require extensive intensive care and

Table 2. Article Prognostic Factors and Proposed Mitigating Actions for Firearm-Related TBI

Article #	Author	Prognostic factors	Proposed mitigation action
1	Deng et al,[3] 2019	GCS score 3–8 (risk of death 39.4 OR) unknown GCS (10.6 OR), ISS 25–75 (8.1 OR), and emergency department hypotension (5.1 OR); Medicare/Medicaid insurance had prolonged hospital length of stay (mean increase 4.4 days) compared with private insurance	Different US regions may have varying GSWH management, warranting further research. Restricting gun access may reduce firearm deaths and consumption of public healthcare resources
2	Efron et al,[33] 2006	Most mortalities (48.3%) demonstrated severe penetrating injuries to the head	Implement violence prevention programs, pursue aggressive firearm policies to limit access, and address the influence of depressed socioeconomic status
3	McNickle et al,[36] 2020	Self-inflicted injuries made up 68% of deaths. Patients with SMR had increased the use of cervical spine CT	Avoid prehospital SMR for suspected self-inflicted injuries, and SMR should be discontinued for other cases after negative CT imaging
4	Finlay-Morreale et al,[43] 2009	Intimate partner violence saw a 10-fold fatality rate compared with violence from an acquaintance or stranger. Victim was 3.8 times more likely to die if the assault occurred at home compared with in public	Reduce firearm access for perpetrators of intimate partner violence
5	Mansour et al,[19] 2021	Mortality was more common in coagulopathic patients (73%) than in noncoagulopathic (25%) patients	Coagulopathy, low GCS scores, and radiographic indicators should be used in the identification of severely affected firearm-TBI phenotypes. Future work should investigate coagulopathy reversal before 24 hours
6	Wertheimer et al,[45] 2008	Age or years of education did not differ between TBI severity stratifications	Authors present evidence that treating patients with a GCS score of 8 or less is not futile and community reintegration is achievable
7	Yang et al,[5] 2022	The proportion of assault and self-inflicted cGSWs increased during the COVID-19 pandemic	Future pandemic protocols should implement preparations for an increase in serious neurotrauma cases
8	Murphy et al,[16] 2016	GCS score lower than 9 and CNS involvement had a higher mortality rate (70%). Temporal and frontal scalp GSWH had highest mortality rates. Avulsive status had an improved survival. Positive toxicology screen was associated with improved survival. INR > 1.1 was associated with an increased mortality rate	Advocating for damage control resuscitation and surgery may improve survival; A 1:1:1 ratio of packed red blood cells, fresh frozen plasma, and platelets is recommended
9	Chopra et al,[38] 2018	Neither location of injury, type of gun used, or mechanism of injury predicted visual loss outcome	Survivors of gun trauma to the head suffer long-term visual damage at high rates. Ophthalmologists should be involved in the management of these cases and patient council
10	Lustenberger et al,[46] 2011	GSC score less than 8, ISS greater than 16, and hypotension on admission were associated with poorer survival. Older age was associated with an increased mortality rate	Introduce suicide intervention programs in care facilities for the elderly
11	Chiu et al,[23] 2019	African American patients were less frequently directed to immediate care and rehabilitation facilities compared with Caucasian patients	There seems to be other factors influencing suggested racial biases, such as insurance status. Standardization of insurance coverage could help eliminate minorities' barriers to high-value trauma care
12	Molina et al,[24] 2013	Men tend to commit suicide more often than women. Most suicides (82%) are firearm-related traumatic brain injuries	N/A
13	Kercher et al,[44] 2013	Nearly one-fifth of interpersonal violence perpetrators had previous weapon violations	Domestic disturbance calls pose risks to law enforcement officers and IPV-victims. Enforcing firearm removal orders can increase safety for both groups

TABLE 2. Continued.

Article #	Author	Prognostic factors	Proposed mitigation action
14	Algattas et al,[6] 2021	There was a 50% increase in GSWs leading to neurotrauma compared with pre–COVID-19 years; assaults increased in 2020 but self-inflicted were unchanged	Characterizing initial response to statewide shutdowns would help inform on the effects of societal mandates on resources, staff availability, and changes in mechanism and locations of neurotraumas
15	Loder & Farren,[12] 2014	A significant percentage of hunting injuries (11.9%) occur in younger people (14 years or younger)	N/A
16	Schellenberg et al,[31] 2022	Patients with stab wounds were treated surgically more often than those with GSWs; however, most likely due to GSW victims exsanguinating before arrival	Firearm-related interpersonal violence is the leading cause of vertebral artery injuries, highlighting the need for violence prevention in public health
17	Graves et al,[34] 2021	Prehospital mortality has *increased* over time, while in-hospital mortality has *decreased* over time	The concerning trend in *increased* prehospital mortality should encourage further research into identifying contributing factors across various transitions of care
18	Aarabi et al,[35] 2014	Factors such as a low GCS score at admission, crossing of (x, y, and z) planes, APR to light, vanishing basal cisterns, and intraventricular hematoma indicated a higher risk of poor survival	Entry of small pellets into the brain through a minor opening does not require complex surgical management; local wound care, antibiotic administration, and skin closure are most appropriate
19	Crutcher et al,[17] 2016	GCS score at admission and length of stay were strongest predictors of survival. Patients with insurance were 5 times more likely to survive	Community-level campaigns that seek to alleviate social stigma surrounding mental illness could target social isolation and discrimination. Restricting gun access could remove firearms from violent offenders and reduce firearm suicide
20	Quenzer et al,[25] 2021	Patients who sustained GSW from a handgun were more severely injured compared with other firearm types; more likely to present as hypotensive and with a GCS score <9	Screenings and preventative programs should be aimed toward older, White male handgun owners due to the demographic posing the highest risk of suicide. Lethal means counseling should especially be performed when anxiety and depression are reported
21	Coronado et al,[64] 2011	Highest mortality among persons aged 75 years or older. However, a substantial number of deaths occur in boys age 10–14 years	Interventions should target behavior (eg, safe storage, counseling), products (eg, designing child-proof firearms), and policy (eg, licensing requirements, gun storage laws)
22	Richmond & Lemaire,[32] 2008	US life expectancy drops by 3.1 days due to shorter lifespans for individuals who survive initial cranial GSWs	N/A

CNS, central nervous system; CT, computed tomography; GCS, Glasgow Coma Scale; GSW, gunshot wound; GSWH, gunshot wound to the head; IPV, interpersonal violence; ISS, injury severity score; N/A, not available; OR, odds ratio; SMR, spinal motion restriction; TBI, traumatic brain injury.

prolonged hospital stays, with a median intensive care unit LOS of 6 days, mechanical ventilation for 2.5 days, and a median hospital LOS of 14 days.[36] The costs associated with these admissions are substantial, with a mean emergency department cost of $5192 and a mean inpatient cost of $103 765 for a mean hospital LOS of 7.2 days.[37] Among 18 surviving patients at 1 center, all sustained ocular injuries, with 28% having bilateral injuries and 72% having injuries in 1 eye. Long-term visual damage was experienced by 44% of these patients with only 56% showing improvement.[38]

Injury-related complications significantly contribute to morbidity, particularly vascular complications such as vasospasm, traumatic intracranial aneurysm, and venous sinus occlusion, and increasing risk of infection beyond the first week postinjury.[39] Cerebrospinal fluid leakage, commonly resulting from dura mater lacerations, was most frequent in orbitofrontal and transtemporal patterns of injury. Finally, post-traumatic epilepsy is a prevalent complication that can manifest either early or late in patients with firearm-related TBI. These injury-related sequelae contribute to a 2.5 times increased risk of death compared with the general population.[40]

Proposed Medical and Social Actions for Mitigating Firearm-Related TBIs

Medical Proposed Action

The discontinuation of prehospital spinal motion restriction (SMR) for self-inflicted cranial GSWs is suggested, as spinal injury is rare in these cases.[36] Computed tomography (CT) imaging can

be time-consuming and unnecessary, and spinal immobilization may offer limited benefits while carrying a high potential for harm.[41] Avoiding prehospital SMR for self-inflicted injuries and discontinuing SMR after obtaining CT imaging negative for fractures are advised.[36] These recommendations align with emergency medical service contraindications for SMR, which include the absence of spinal injury, compromised airway management or ventilation, hemorrhage control, and cardiac arrest.[42]

Identifying severe firearm-related TBI phenotypes can be achieved by assessing coagulopathy status, defined as an international normalized ratio >1.3, platelet count <100 000/μL, or partial thromboplastin time >37 seconds.[19] Patients with coagulopathies exhibited a significantly higher mortality rate (73%), while those who resolved coagulopathy after 24 hours had improved survival compared with those who remained coagulopathic (75% vs 38%).[19] Further investigation into the potential causal relationship and the role of active coagulopathy reversal in penetrating brain injuries is recommended.

Social Proposed Action

Implementing violence prevention programs in socioeconomically disadvantaged areas, where gun-related assaults are more prevalent, could educate at-risk youth about interpersonal conflict and aggression,[33] alongside advocating for local ordinances that enhance gun safety and firearm access restrictions. Stricter enforcement of firearm removal orders in cases involving IPV can also decrease intimate partner homicides.[43,44] Community reintegration programs play a vital role in enhancing functional outcomes for individuals with severe cranial GSWs.[45] Acute rehabilitation has demonstrated significant improvements in functionality, particularly within the first year postinjury, even among those with initial low GCS scores of 3, 4, or 5.[45] Furthermore, suicide intervention programs in care facilities and communities catering to the elderly are strongly recommended, considering the higher prevalence of self-inflicted cranial GSWs among individuals aged 75 years and older.[46]

DISCUSSION

Clinical Assessment and Prognostic Factors in Cranial GSWs

The GCS score has long been recognized as a valuable tool in assessing trauma severity and predicting outcomes in cranial GSWs.[47] Low GCS scores consistently correlated with poor survival rates and lead to the development of scoring and management systems.[48-50] A prospective study reported that patients with GCS scores of 3–5 had no favorable recoveries and suggested limited surgical intervention unless significant extra-axial hematomas are present.[49] However, others advocate for aggressive surgical treatment in most cases, except when irreversible neurological compromise is evident.[50] Gressot et al[51] reported distinct cranial GSW mortality rates based on GCS score, age, pupil reactivity, and bullet trajectory. This scoring system was subsequently externally validated.[52,53] The reliability of GCS scores as independent prognostic predictors for survival in cranial GSWs is supported by our review, along with basal cistern effacement on CT, missile trajectory, intraventricular hemorrhage, and high injury severity scores scores.[35]

Hypotension and hypercoagulable hemostatic disturbances also contribute to increased mortality in firearm-related TBI. Studies have shown that a significant proportion of patients experience coagulopathy, resulting in higher mortality rates.[54] Coagulopathic patients typically present with lower GCS scores, particularly in the motor component, which is a well-established predictor of mortality in penetrating TBI cases.[19] The association between coagulopathy and low GCS scores supports the consideration of coagulopathic status for identification of severe phenotypes.

Risk Factors and Social Intervention Strategies

Efforts to reduce firearm-related TBI in the United States focus on policy reform and gun access regulation, as studies demonstrate their impact on reducing homicides, nonfatal shootings, and gang-related incidents.[55] Regional distribution highlights the prevalence of firearm injuries in the South and West regions, prompting examination of state-level firearm laws. Extensive literature reports an association between more restrictive state firearm regulations and decreased fatalities, lower household firearm ownership, reduced female firearm deaths, and decreased homicide and suicide rates.[56-60] Stronger background checks were specifically associated with lower firearm fatality rates, supporting the need for effective public policies and increased funding for gun violence prevention research.

Firearm-related suicides contribute to nearly half of the overall increase in gun-related deaths in the past decade.[4] Firearm ownership and availability significantly increases the risk for suicide; this could affect any of the one-third of gun-owning Americans.[61,62] Young adults and the elderly face elevated vulnerability to suicide, with suicide rates among young adults increasing by 55% from 2007 to 2017 and elderly firearm suicides rising by 49% between 2010 and 2018.[63-65] The prevalence of depression within the elderly population also correlates with the increase in elderly firearm suicides.[13] Implementing suicide intervention programs in care facilities and communities may reduce self-inflicted cranial GSWs among the elderly and provide vital support. Stricter enforcement of firearm removal orders in cases of IPV may also decrease assault and homicide rates. While federal law prohibits individuals subject to a final domestic violence restraining order from possessing firearms and ammunition, effective procedures for removing these firearms are lacking in many states which limits the effectiveness of legislation.[14,43]

Limitations

Limitations of our review stem from heterogeneity of end points, diverse data collection methods, and variation in relevant factors across different centers, which constrained available data

for extraction. Furthermore, the absence of operative outcomes and surgical approaches in the included articles hindered their evaluation. Included articles spanned different periods limiting our ability to assess current trends and guideline outcomes, underscoring the need for future systematic prospective research. Importantly, older publications may underrepresent the influence of societal factors, such as history of domestic violence and gun laws, on GSW-related TBI prevalence. Despite these limitations, our scoping review comprehensively examines the epidemiology, predictive factors, and mitigation strategies in adult firearm-related TBIs. To ensure methodological rigor, we collaborated with a professional medical librarian who used a method previously used in systematic scoping reviews.[55]

CONCLUSION

Firearm-related TBI significantly burdens morbidity and mortality in the United States. This review emphasizes its impact on young adult men through assault and vulnerable populations such as depressed elderly individuals and women experiencing IPV. Key clinical indicators, including low GCS scores, CNS involvement, hypotension, and coagulopathies, play a pivotal role in evaluating cranial GSW patients. Optimal surgical management should prioritize coagulopathy management, addressing intracranial hemorrhage, and managing complications. Proposed interventions encompass stricter firearm regulations, identification of vulnerable populations, violence prevention programs, and community reintegration initiatives. Medical strategies involve using coagulopathy to identify severe TBI phenotypes, exploring coagulopathy reversal, and updating prehospital SMR guidelines. Prospective multicenter studies are essential to evaluate intervention effectiveness and improve cranial GSW management, evidence-based training, and advocacy efforts.

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REFERENCES

1. Center for Gun Violence Solutions. U.S. Gun Violence in 2021: An Accounting of a Public Health Crisis. 2023. Accessed June 21, 2023. https://publichealth.jhu.edu/sites/default/files/2023-06/2023-june-cgvs-u-s-gun-violence-in-2021.pdf
2. Gramlich J. What the Data Says about Gun Deaths in the U.S. 2022. Accessed January 4, 2023. https://policycommons.net/artifacts/2232815/what-the-data-says-about-gun-deaths-in-the-us/2990720/
3. Deng H, Yue JK, Winkler EA, Dhall SS, Manley GT, Tarapore PE. Adult firearm-related traumatic brain injury in United States trauma centers. *J Neurotrauma.* 2019;36(2):322-337.
4. Centers for Disease Control and Prevention. *Surveillance Report of Traumatic Brain Injury-Related Deaths by Age Group, Sex, and Mechanism of Injury—United States, 2018 and 2019*. Centers for Disease Control and Prevention, U.S. Department of Health and Human Services; 2022.
5. Yang GL, Johnson MD, Solomon D, et al. The effects of the COVID-19 pandemic on penetrating neurotrauma at a level 1 trauma center. *World Neurosurg.* 2022;164:e530-e539.
6. Algattas HN, McCarthy D, Kujawski B, et al. Impact of coronavirus disease 2019 shutdown on neurotrauma volume in Pennsylvania. *World Neurosurg.* 2021;151:e178-e184.
7. Pino EC, Gebo E, Dugan E, Jay J. Trends in violent penetrating injuries during the first year of the COVID-19 pandemic. *JAMA Netw Open.* 2022;5(2):e2145708.
8. Amin D, Manhan AJ, Smith RN, Roser SM, Abramowicz S. Frequency of firearm injuries to head and neck increased during covid-19 pandemic. *J Oral Maxillofac Surg.* 2021;79(11):2299-2305.
9. Ssentongo P, Fronterre C, Ssentongo AE, et al. Gun violence incidence during the COVID-19 pandemic is higher than before the pandemic in the United States. *Sci Rep.* 2021;11(1):20654-20658.
10. Bridge JA, Ruch DA, Sheftall AH, et al. Youth suicide during the first year of the COVID-19 pandemic. *Pediatrics.* 2023;151(3):e2022058375.
11. Ouzzani M, Hammady H, Fedorowicz Z, Elmagarmid A. Rayyan—a web and mobile app for systematic reviews. *Syst Rev.* 2016;5(1):210.
12. Loder RT, Farren N. Injuries from firearms in hunting activities. *Injury.* 2014;45(8):1207-1214.
13. Price JH, Khubchandani J. Firearm suicides in the elderly: a narrative review and call for action. *J Community Health.* 2021;46(5):1050-1058.
14. Cloud LK, Prood N, Ibrahim J. Disarming intimate partner violence offenders: an in-depth descriptive analysis of federal and state firearm prohibitor laws in the United States, 1991-2016. *J Interpers Violence.* 2023;38(5-6):5164-5189.
15. Kivisto AJ, Porter M. Firearm use increases risk of multiple victims in domestic homicides. *J Am Acad Psychiatry Law.* 2020;48(1):26-34.
16. Murphy JA, Lee MT, Liu X, Warburton G. Factors affecting survival following self-inflicted head and neck gunshot wounds: a single-centre retrospective review. *Int J Oral Maxillofac Surg.* 2016;45(4):513-516.
17. Crutcher CL 2nd, Fannin ES, Wilson JD. Racial disparities in cranial gunshot wounds: intent and survival. *J Racial Ethnic Health Disparities.* 2016;3(4):687-691.
18. Alexander S, Kerr ME, Yonas H, Marion DW. The effects of admission alcohol level on cerebral blood flow and outcomes after severe traumatic brain injury. *J Neurotrauma.* 2004;21(5):575-583.
19. Mansour A, Loggini A, Goldenberg FD, et al. Coagulopathy as a surrogate of severity of injury in penetrating brain injury. *J Neurotrauma.* 2021;38(13):1821-1826.
20. Kriet JD, Stanley RB, Jr, Grady MS. Self-inflicted submental and transoral gunshot wounds that produce nonfatal brain injuries: management and prognosis. *J Neurosurg.* 2005;102(6):1029-1032.
21. Johnson J, Markiewicz MR, Bell RB, Potter BE, Dierks EJ. Gun orientation in self-inflicted craniomaxillofacial gunshot wounds: risk factors associated with fatality. *Int J Oral Maxillofac Surg.* 2012;41(8):895-901.
22. Asemota AO, George BP, Cumpsty-Fowler CJ, Haider AH, Schneider EB. Race and insurance disparities in discharge to rehabilitation for patients with traumatic brain injury. *J Neurotrauma.* 2013;30(24):2057-2065.
23. Chiu RG, Fuentes AM, Mehta AI. Gunshot wounds to the head: racial disparities in inpatient management and outcomes. *Neurosurg Focus.* 2019;47(5):E11.
24. Molina DK, DiMaio VJM, Cave R. Handgun wounds: a review of range and location as pertaining to manner of death. *Am J Forensic Med Pathol.* 2013;34(4):342-347.
25. Quenzer F, Givner A, Dirks R, Coyne CJ, Ercoli F, Townsend R. Self-inflicted gun shot wounds: a retrospective, observational study of U.S. Trauma Centers. *West J Emerg Med.* 2021;22(3):518-524.
26. Maghami S, Hendrix C, Matecki M, et al. Comparison of the causes of death and wounding patterns in urban firearm-related violence and civilian public mass shooting events. *J Trauma Acute Care Surg.* 2020;88(2):310-313.
27. Brain Trauma Foundation. Guidelines for the Management of Severe TBI, 4th Edition. 2016. Accessed August 26, 2023. https://braintrauma.org/coma/guidelines/guidelines-for-the-management-of-severe-tbi-4th-ed
28. Brain Trauma Foundation. Guidelines for the Surgical Management of TBI. 2006. Accessed August 26, 2023. https://braintrauma.org/coma/guidelines/guidelines-for-the-surgical-management-of-tbi

29. Johnson M, Carroll C, Cass D, Andaluz N, Goodman M, Ngwenya LB. A level I trauma center's five-year experience with aggressive management of civilian cranial gunshot wounds. 2018;35(16).
30. Joseph B, Aziz H, Pandit V, et al. Improving survival rates after civilian gunshot wounds to the brain. *J Am Coll Surg.* 2014;218(1):58-65.
31. Schellenberg M, Owattanapanich N, Cowan S, et al. Penetrating injuries to the vertebral artery: interventions and outcomes from US Trauma Centers. *Eur J Trauma Emerg Surg.* 2022;48(1):481-488.
32. Richmond TS, Lemaire J. Years of life lost because of gunshot injury to the brain and spinal cord. *Am J Phys Med Rehabil.* 2008;87(8):609-618; quiz 615-618.
33. Efron DT, Haider A, Chang D, Haut ER, Brooke B, Cornwell EE 3rd. Alarming surge in nonsurvivable urban trauma and the case for violence prevention. *Arch Surg.* 2006;141(8):800-803; discussion 803-5.
34. Graves WC, Oyesanya TO, Gormley M, et al. Pre- and in-hospital mortality for moderate-to-severe traumatic brain injuries: an analysis of the National Trauma Data Bank (2008-2014). *Brain Inj.* 2021;35(3):265-274.
35. Aarabi B, Tofighi B, Kufera JA, et al. Predictors of outcome in civilian gunshot wounds to the head. *J Neurosurg.* 2014;120(5):1138-1146.
36. McNickle AG, Chestovich PJ, Fraser DR. Cervical spine injury is rare in self-inflicted craniofacial gunshot wounds: an institutional review and comparison to the US National Trauma Data Bank (NTDB). *Prehosp Disaster Med.* 2020;35(5):524-527.
37. Allareddy V, Rampa S, Nalliah R, Lee MK, Auslender M, Allareddy V. 507: is it time for code GSW (gunshot wound)? 194 adult ED visits a day! *Crit Care Med.* 2016;44(12):203.
38. Chopra N, Gervasio KA, Kalosza B, Wu AY. Gun trauma and ophthalmic outcomes. *Eye.* 2018;32(4):687-692.
39. Van Wyck DW, Grant GA. Penetrating traumatic brain injury: a review of current evaluation and management concepts. *J Neurol Neurophysiol.* 2015;06(06):1-7.
40. Ventura T, Harrison-Felix C, Carlson N, et al. Mortality after discharge from acute care hospitalization with traumatic brain injury: a population-based study. *Arch Phys Med Rehabil.* 2010;91(1):20-29.
41. Haut ER, Kalish BT, Efron DT, et al. Spine immobilization in penetrating trauma: more harm than good?. *J Trauma Inj Infect Crit Care.* 2010;68(1):115-121; discussion 120-1.
42. Southern Nevada Health District. Clark County EMS System Emergency Medical Care Manual. 2017. Accessed August 26, 2023. https://www.southernnevadahealthdistrict.org/ems/documents/ems/medical-care-protocols.pdf
43. Finlay-Morreale HE, Tsuei BJ, Fisher BS, Davis K, Johannigman JA. Close is dead: determinants of firearm injury lethality in women. *J Trauma Inj Infect Crit Care.* 2009;66(4):1207-1211.
44. Kercher C, Swedler DI, Pollack KM, Webster DW. Homicides of law enforcement officers responding to domestic disturbance calls. *Inj Prev.* 2013;19(5):331-335.
45. Wertheimer JC, Hanks RA, Hasenau DL. Comparing functional status and community integration in severe penetrating and motor vehicle-related brain injuries. *Arch Phys Med Rehabil.* 2008;89(10):1983-1990.
46. Lustenberger T, Inaba K, Schnüriger B, et al. Gunshot injuries in the elderly: patterns and outcomes. A national trauma databank analysis. *World J Surg.* 2011;35(3):528-534.
47. Teasdale G, Maas A, Lecky F, Manley G, Stocchetti N, Murray G. The Glasgow Coma Scale at 40 years: standing the test of time. *Lancet Neurol.* 2014;13(8):844-854.
48. Šustić A, Turina D, Šustić A, et al. War head injury score: an outcome prediction model in War casualties with acute penetrating head injury. *Mil Med.* 2001;166(4):331-334.
49. Grahm TW, Williams FC, Jr, Harrington T, Spetzler RF. Civilian gunshot wounds to the head: a prospective study. *Neurosurgery.* 1990;27(5):696-700; discussion 700.
50. Martins RS, Siqueira MG, Santos MTS, Zanon-Collange N, Moraes OJS. Prognostic factors and treatment of penetrating gunshot wounds to the head. *Surg Neurol.* 2003;60(2):98-104; discussion 104.
51. Gressot LV, Chamoun RB, Patel AJ, et al. Predictors of outcome in civilians with gunshot wounds to the head upon presentation. *J Neurosurg.* 2014;121(3):645-652.
52. Kelly PD, Patel PD, Yengo-Kahn AM, et al. Incorporating conditional survival into prognostication for gunshot wounds to the head. *J Neurosurg.* 2021;135(5):1550-1559.
53. Yengo-Kahn AM, Patel PD, Kelly PD, et al. The value of simplicity: externally validating the Baylor cranial gunshot wound prognosis score. *J Neurosurg.* 2021;135(5):1560-1568.
54. Folkerson LE, Sloan D, Davis E, et al. Coagulopathy as a predictor of mortality after penetrating traumatic brain injury. *Am J Emerg Med.* 2018;36(1):38-42.
55. Gadot R, LoPresti MA, Smith DN, Ouellette L, Lam S. Firearm-related pediatric head trauma: a scoping review. *Neurosurgery.* 2022;91(2):239-246.
56. Kalesan B, Mobily ME, Keiser O, Fagan JA, Galea S. Firearm legislation and firearm mortality in the USA: a cross-sectional, state-level study. *Lancet.* 2016;387(10030):1847-1855.
57. Alban RF, Nuño M, Ko A, Barmparas G, Lewis AV, Margulies DR. Weaker gun state laws are associated with higher rates of suicide secondary to firearms. *J Surg Res.* 2018;221:135-142.
58. Liu Y, Siegel M, Sen B. Neighbors do matter: between-state firearm laws and state firearm-related deaths in the U.S., 2000-2017. *Am J Prev Med.* 2020;59(5):648-657.
59. Fleegler EW, Lee LK, Monuteaux MC, Hemenway D, Mannix R. Firearm legislation and firearm-related fatalities in the United States. *JAMA Intern Med.* 2013;173(9):732-740.
60. Sanchez C, Jaguan D, Shaikh S, McKenney M, Elkbuli A. A systematic review of the causes and prevention strategies in reducing gun violence in the United States. *Am J Emerg Med.* 2020;38(10):2169-2178.
61. Kalesan B, Villarreal MD, Keyes KM, Galea S. Gun ownership and social gun culture. *Inj Prev.* 2016;22(3):216-220.
62. Mann JJ, Michel CA. Prevention of firearm suicide in the United States: what works and what is possible. *Am J Psychiatry.* 2016;173(10):969-979.
63. Miller GF, Lyons BH, Peterson AB, Rice KL, Holland KM. Reported history of traumatic brain injury among suicide decedents: national violent death reporting system, 2003-2017. *Am J Prev Med.* 2021;61(4):501-508.
64. Coronado VG, Xu L, Basavaraju SV, et al. Surveillance for traumatic brain injury-related deaths--United States, 1997-2007. *MMWR Surveill Summ.* 2011;60(5):1-32.
65. Gunn JF 3rd, Boxer P. Youth gun and weapon carrying and suicide rates for those aged 24 Years and younger, 2005-2017. *J Adolesc Health.* 2022;70(3):457-462.

COMMENTS

The rising gun violence epidemic in USA results to an increase of firearm-related TBI. In this article 22 reviewed studies revealed some important interventions such as coagulopathy reversal and prehospital stabilization in order to reduce incidence and mortality of this type of injury. It is a well-designed study with wide inclusion criteria and clearly communicated. Coagulopathy after severe TBI belongs to well-known complications directly after the incident. In gunshot injuries the optimal management of this disturbance plays a pivotal role when there is a need of surgical intervention, especially with major intracranial hemorrhages or hematomas. The reversal procedure should be based on approved guidelines in order to improve outcome rates. Avoiding hypotension and complicated infections in penetrating cases would add to minimize hospital stay and reduce morbidity. The prehospital management is pointed in this article as a major medical intervention reflecting to an effective management of gunshot injuries. Author provided clear recommendations in this time of injury as well as the prognostic significance of CT findings and GCS at admission. This article could also contribute to a more restrictive regulation about gun access in young adults. Responsible state authorities should implement suicide intervention programs for these populations. The present detailed study of gunshot injuries should be a future guideline for similar studies in other countries to provide evidence-based bias.

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Firearm associated traumatic brain injury (TBI)is a growing concern and significant public health issue in the United States. The article "Firearm-Related Traumatic Brain Injuries in Adults" reports on the scope of firearm-related TBIs, prognostic factors, and recommended

interventions for improvement in outcomes using a scoping review of existing literature to incorporate a broad variety of firearm-related injury and reporting methods. The article demonstrates a comprehensive review of the existing literature in firearm-related injuries and was broad in its inclusion criteria, discussing multiple types of weapons and mechanisms of injury.

Though well designed and thorough in reporting, this article may have been strengthened by the inclusion of the pediatric population, either in the whole of the analysis or as a subpopulation evaluation. Unfortunately, children have not been excluded from the rise in firearm injuries, and are victims of all mechanisms, including assault (eg, gang violence), self-inflicted which is often survived with high morbidity, and accidental. Acknowledging the scope of this study was focused on the adult population, the exclusion of a large faction of the population minimizes the scope of the problem as a whole and limits the data available to policy makers and activists concerned with protecting all potential victims.

This article goes beyond simply presenting the prevalence and clinical factors of firearm injuries by discussing the public health implications of these injuries and proposed mechanisms for reducing these avoidable catastrophes. The authors address the urgent need for both preventative measures in society and actionable changes in medical training that may lead to improved outcomes. Overall, the article provides a valuable contribution to the existing literature and should serve as a call to awareness for an important and increasing source of preventable morbidity and mortality in our communities.

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I greatly welcome this scoping review as it calls attention to the increasing problem of firearm-related traumatic brain injuries with high mortality and substantial morbidity—all of which are preventable! To me—as European neurosurgeon—it is very difficult to understand the strong gun lobby and wide dissemination of firearms in the US, which contribute to the high incidence of firearm-related injuries, causing a total of 48 830 gun-related deaths annually.

In their scoping review Reyes et al[1a] highlight the public health burden posed by cerebral gunshot injuries, high fatality rates, regional variations with the highest incidence in southern States, vulnerable populations and disparities in care. African Americans are at particular risk. Vulnerable populations include the elderly and women experiencing interpersonal violence. The widespread availability of firearms undoubtedly contributed to the use of firearms by abusers. Uninsured patients had higher mortality rates and were less often refererred to rehabilitation on discharge. Proposed social actions to reduce the public health burden of firearm-related TBI include violence prevention programs in socioeconomically disadvantaged areas, enhanced gun safety and firearm access restrictions, as well as suicide intervention programs in care facilities and communities catering to the elderly. Valid as these recommendations are, I would suggest that a cultural change in the US is required in which gun posession is no longer considered the norm and automatic weapons are banned.

On a minor point of critique, I doubt if the statement that "the Brain Trauma Foundation's clinical and surgical management guidelines recommend aggressive management strategies for TBI in cranial GSW patients" is correct. I may be wrong, but I don't think these guidelines address penetrating TBI (PBI). In fact, the fourth edition of the BTF guidelines on management of TBI[2a] specifically exclude patients with penetrating TBI (Appendix E). Neither do the surgical guidelines[3a] specifically address PBI. Dedicated guidelines for the management and prognosis of PBI were published by Aarabi et al in 2001.[4a] An initiative to update these guidelines is currently underway.

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1a. Reyes G, Gadot R, Ouellette L, et al. Firearm-related traumatic brain injuries in adults: a scoping review. *Neurosurgery.* 2023;94(2):229-239.
2a. *Guidelines for the Management of Severe TBI, 4th Edition*. Brain Trauma Foundation. 2016. Accessed September 15, 2023. https://braintrauma.org/coma/guidelines/guidelines-for-the-management-of-severe-tbi-4th-ed
3a. *Guidelines for the Surgical Management of TBI*. Brain Trauma Foundation. 2006. Accessed September 15, 2023. https://braintrauma.org/coma/guidelines/guidelines-for-the-surgical-management-of-tbi
4a. Aarabi B, Alden TD, Chesnut RM, et al Management and prognosis of penetrating brain injury. *J Trauma* 2001;51(2 Suppl):s1-s86.