The effect of gun control laws on hospital admissions for children in the United States

Jun Tashiro, MD, MPH, Rebecca S. Lane, Lawrence W. Blass, MD,
Eduardo A. Perez, MD, *and* **Juan E. Sola, MD**, *Miami, Florida*

BACKGROUND: Gun control laws vary greatly between states within the United States. We hypothesized that states with strict gun laws have lower mortality and resource utilization rates from pediatric firearms-related injury admissions.

METHODS: Kids' Inpatient Database (1997–2012) was searched for accidental (E922), self-inflicted (E955), assault (E965), legal intervention-related (E970), or undetermined circumstance (E985) firearm injuries. Patients were younger than 20 years and admitted for their injuries. Case incidence trends were examined for the study period. Propensity score–matched analyses were performed using 38 covariates to compare outcomes between states with strict or lenient gun control laws.

RESULTS: Overall, 38,424 cases were identified, with an overall mortality of 7%. Firearm injuries were most commonly assault (64%), followed by accidental (25%), undetermined circumstance (7%), or self-inflicted (3%). A small minority involved military-grade weapons (0.2%). Most cases occurred in lenient gun control states (48%), followed by strict (47%) and neutral (6%).On 1:1 propensity score–matched analysis, in-hospital mortality by case was higher in lenient (7.5%) versus strict (6.5%) states, $p = 0.013$. Lenient states had a proportionally higher rate of accidental (31%) and self-inflicted injury (4%) versus strict states (17% and 1.6%, respectively), $p < 0.001$. Assault-related injuries were proportionally lower in lenient (54%) versus strict (75%) states, $p < 0.001$. Military-grade weapons were more common in lenient (0.4%) versus strict (0.1%) states, $p = 0.001$.

CONCLUSIONS: These findings highlight the importance of legislative measures and their role in injury prevention, as firearm injuries are entirely avoidable mechanisms of injury. Lenient gun control contributes not only to worse outcomes per case, but also to a more significant and detrimental impact on public health. (*J Trauma Acute Care Surg.* 2016; 81: S54–S60. Copyright © 2016 Wolters Kluwer Health, Inc. All rights reserved.)

LEVEL OF EVIDENCE: Epidemiologic study, level III.

KEY WORDS: Firearms; gunshot wounds; legislation; violence.

Too often, children are the unintended victims of the widespread availability of firearms. This reality poses an important issue for health professionals taking care of pediatric patients, in that firearms remain a significant source of preventable injury among children and adolescents across the United States.[1–3] In particular, adolescents 12 to 19 years of age and African Americans are at highest risk of becoming victims.[1] Pediatric firearms outcomes have been examined in prior studies; specifically, recent studies have performed comparisons based on the presence of "Stand Your Ground" or Child Access Prevention laws in certain states.[4,5] Others have described the epidemiology[6] and lower rates of pediatric firearm injury in strict firearm law states[7]; these analyses, however, were limited 1-year cross-sectional cohorts.

One of the main obstacles in achieving uniform improvements in gun control is the variability of laws between states.[2,4,7–13] Regulations differ from strict states with the most stringent laws for purchase, ownership, carrying, and gun-related crime investigation to lenient states that allow firearms in schools and other public places, purchases without licensure, and concealed carry without permits.[4,7,11,12,14] In this setting, the trafficking of firearms across state lines, most often diffusion to areas with strict gun control laws, becomes a naturally lucrative business—and an important regulatory problem.[10,15] The Brady Campaign to Prevent Gun Violence is an organization that provides information on firearms regulation and interventions for preventing gun violence. In an effort to objectively classify states and their stringency in firearms regulation, a scorecard with a grading system is published to determine states' areas of improvement.

Several prior studies have linked rigorous legislation to lower rates of suicide[2,9,16] and homicide,[2,16] lower rates of youth gun carrying,[8] and overall improved outcomes in the setting of firearms-related injuries.[7,12] As a major source of violence-related injury death among all age groups in the United States, firearms-related injuries remain a perpetually important public health issue with heavy political implications.[3] To date, pediatric firearm injuries have not been examined using a large, population-based database with an analysis of incidence trends and a matched comparison of firearms injuries between strict and lenient gun control law states. In this report, we compared states with strict versus lenient gun regulations, based on Brady Campaign criteria, to assess outcomes of firearms-related pediatric hospital admissions. We hypothesized that worse outcomes

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From the Division of Pediatric Surgery, DeWitt-Daughtry Department of Surgery, University of Miami Miller School of Medicine, Miami, Florida.
J.T. and R.S.L. contributed equally to this study.
Address for reprints: Juan E. Sola, MD, Division of Pediatric Surgery, DeWitt-Daughtry Family Department of Surgery, Leonard M. Miller School of Medicine, University of Miami, 1120 NW 14th St, Suite 450K, Miami, FL 33136; email: JSola@med.miami.edu.

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are related to lenient gun regulation states compared with those with strict regulations. Using these findings, we aim to contribute to intervention planning for this important public health issue.

MATERIALS AND METHODS

The Kids' Inpatient Database (KID) is a sample of pediatric admissions, maintained by the Agency for Healthcare Research and Quality.[17] Each triennial release contains data on up to 7.5 million weighted cases. Diagnoses and procedures are coded using the *International Classification of Diseases, Ninth Revision, Clinical Modification*. The sampling of pediatric hospitalizations is standardized prior to inclusion in the database release, and quality is ensured following strict guidelines set by the Healthcare Cost and Utilization Project (HCUP).[18] Statistics were reviewed by a third-party contractor for each year and data source, and data were cleaned according to the quality control philosophy as published in the HCUP Quality Control Procedures.[18]

We identified cases of pediatric (<20 years) firearms injuries from the 1997, 2000, 2003, 2006, 2009, and 2012 releases of the KID. These data sets represent all of the data available from the KID. Injury E-codes for accidental (E922), self-inflicted (E955), assault (E965), legal intervention-related (E970), or undetermined circumstance (E985) firearm injuries were used. Patients with dispositions coded as "transfer to short-term hospital" and "other transfers, including skilled nursing facility, intermediate care, and other type of facility" were excluded to avoid duplicate reporting. χ^2 Tests were used to examine linearity and presence of trends. The analyses performed compared proportional trends in injury type, mortality rate, and firearm type, among other characteristics. Analysis of variance was used to compare means among multiple groups, as appropriate. Cases were weighted to project national estimates.

States were defined as strict or lenient using the Brady Campaign to Prevent Gun Violence grading method, released as the 2013 State Scorecard.[19] The Brady Campaign criteria evaluate state gun control laws on categories of (1) background checks and access to firearms, (2) other regulation of sales and transfers, (3) gun owner accountability, (4) firearms in public places, (5) classes of weapons and ammunition/magazines, (6) consumer and child safety, (7) investigating gun crimes, (8) local authority to regulate, and (8) other regulations. States with grades "A" to "C+" were considered strict gun control law states, those with "C" were considered to be neutral, and those with "C−" to "F" were considered lenient gun control law states. As the "state" variable is not available for the 1997 and 2012 releases, the state comparisons utilize data derived from the 2000, 2003, 2006, and 2009 releases.

Propensity score (PS)–matched analyses for cases between 2000 and 2009 were performed to compare outcomes of pediatric firearm injuries occurring in states with strict or lenient gun control laws. This method of analysis was selected to directly compare cases occurring in strict and lenient gun control states, while accounting for case variability using multivariate regression modeling. Specifically, a total of 38 demographic, clinical, and comorbidity covariates were used to construct a 1:1 fixed ratio matched cohort. Additional risk-adjustment variables were included using the Elixhauser method, which has been validated in multiple previous retrospective outcome studies.[20–23] Rather than using a number of bivariate methods to compare outcomes, PS-matched analyses provide a more advanced analytical technique to isolate the grouping variable (i.e.,

TABLE 1. Cohort Characteristics of Pediatric Firearm Injuries, KID 1997–2012

Category	n (% of Category)*
Year	
1997	7,121 (19)
2000	6,447 (17)
2003	6,103 (16)
2006	7,725 (20)
2009	6,135 (16)
2012	4,894 (13)
Survival	
Alive	35,788 (93)
Died	2,636 (7)
Sex	
Male	33,812 (89)
Female	4,240 (11)
Race/ethnicity	
White	5,331 (17)
African American	16,616 (54)
Hispanic	6,995 (23)
Asian or Pacific Islander	450 (1.5)
Native American	181 (0.6)
Other	1,090 (4)
Payer status	
Medicare	35 (0.1)
Medicaid	17,249 (45)
Private insurance	10,628 (28)
Self-pay	7,151 (19)
No charge	444 (1.2)
Other	2,743 (7)
Hospital type	
Children's hospital	1,447 (4)
Non-children's hospital	36,977 (96)
Injury type	
Assault	24,534 (64)
Accidental	9,589 (25)
Undetermined circumstance	2,785 (7)
Self-inflicted	1,241 (3)
Legal intervention	275 (0.7)
Gun control laws**	
Strict	11,941 (47)
Lenient	12,291 (48)
Neutral	1,417 (6)
Weapon type	
Handgun	11,871 (77)
Shotgun	2,720 (18)
Hunting rifle	842 (5)
Military-grade weapon	83 (0.5)

Total cohort n = 38,424.
*Percentages limited to available data per category.
**Gun control law type was defined using Brady Campaign criteria, available from 2000–2009.

TABLE 2. Cohort Characteristics of Pediatric Firearm Injuries by Gun Control Regulation Classification, KID 2000–2009

	n (% of Category)*			
Category	**Strict, n = 11,941**	**Lenient, n = 12,291**	**Neutral, n = 1,417**	**Overall, n = 25,649**
Year				
2000	2,551 (21)	3,132 (25)	557 (39)	6,241 (24)
2003	3,112 (26)	2,642 (21)	156 (11)	5,910 (23)
2006	3,787 (32)	3,501 (28)	216 (15)	7,504 (29)
2009	2,491 (21)	3,016 (25)	488 (34)	5,995 (23)
Survival				
Alive	11,223 (94)	11,371 (93)	1,353 (95)	23,947 (93)
Died	718 (6)	920 (7)	64 (5)	1,702 (7)
Sex				
Male	10,506 (91)	10,906 (89)	1,296 (91)	22,708 (90)
Female	1,067 (9)	1,384 (11)	121 (9)	2,572 (10)
Race/ethnicity				
White	874 (9)	2,324 (24)	245 (20)	3,443 (17)
African American	5,186 (53)	5,348 (56)	923 (74)	11,457 (56)
Hispanic	3,151 (32)	1,320 (14)	44 (4)	4,515 (22)
Asian or Pacific Islander	187 (2)	87 (1)	11 (1)	285 (1)
Native American	14 (0)	65 (1)	(1)**	86 (0)
Other	351 (4)	408 (4)	17 (1)	776 (4)
Payer status				
Medicare	(0)**	12 (0)	(0)**	19 (0)
Medicaid	5,939 (50)	4,879 (40)	751 (54)	11,569 (45)
Private insurance	2,952 (25)	3,459 (28)	487 (35)	6,898 (27)
Self-pay	2,114 (18)	2,656 (22)	134 (10)	4,904 (19)
No charge	79 (1)	234 (2)	(0)**	313 (1)
Other	833 (7)	944 (8)	26 (2)	1,803 (7)
Hospital type				
Children's hospital	180 (2)	594 (5)	135 (10)	909 (4)
Non-children's hospital	11,761 (98)	11,697 (95)	1,282 (90)	24,740 (96)
Injury type				
Assault	9,053 (76)	6,680 (54)	815 (57)	16,547 (65)
Accidental	1,979 (17)	3,764 (31)	410 (29)	6,153 (24)
Undetermined circumstance	652 (5)	1,171 (10)	102 (7)	1,925 (8)
Self-inflicted	173 (1)	560 (5)	86 (6)	819 (3)
Legal intervention	84 (1)	116 (1)	(0)**	205 (1)
Weapon type				
Handgun	3,594 (79)	3,818 (72)	381 (74)	7,793 (75)
Shotgun	885 (19)	960 (18)	98 (19)	1,943 (19)
Hunting rifle	81 (2)	451 (9)	35 (7)	567 (5)
Military-grade weapon	17 (0)	39 (1)	(0)**	56 (1)

Total cohort n = 25,649.
*Percentages limited to available data per category.
**Censored values, in accordance with the HCUP Data Use Agreement for the Nationwide Databases.

strict vs. lenient gun control states) as primary difference for comparative analyses. For the matched analyses, cases occurring in the four neutral states (6% of total cohort) were excluded to avoid ambiguity.

All statistical analyses were performed using SPSS Statistics, version 21.0 (IBM, Armonk, New York; 2012). Propensity score value assignment, case sorting, and matching were performed using MatchIt version 2.4–20 (Cambridge, Massachusetts), a supplemental module available for *R* version 2.14.2 (R foundation for Statistical Computing, Vienna, Austria).[24] The institutional review board at the University of Miami Miller School of Medicine (Miami, Florida) deemed this retrospective study to be exempt from full review.

RESULTS

Cohort Demographics

Overall, 38,424 cases were identified, with a cohort in-hospital mortality of 7% during the study period. Median age was 17 years (interquartile range, 2). Most patients tended to be adolescents aged 15 to 19 years (86%), followed by 10 to 15 years (9%), younger than 5 years (3%), and 5 to 10 years

(2%). Patients were most frequently male (89%), African American (54%), and insured (73%) and presented to non–children's hospitals (96%). Firearm injuries were most commonly assault (64%), followed by accidental (25%), undetermined circumstance (7%), or self-inflicted (3%). Most cases involved handguns (77%), followed by shotguns (18%) and hunting rifles (5%). A small minority involved military-grade weapons (0.2%). Most cases occurred in lenient gun control states (48%), followed by strict (47%) and neutral (6%). With regard to the breakdown of state classifications, there were 12 strict, 34 lenient, and 4 neutral states. For additional cohort characteristics, see Tables 1 and 2.

Trend Analysis

Upon analyzing trends, case incidence followed a downward trend through the study period, from 1997 (7,121 cases) to 2012 (4,894 cases) (Fig. 1). Demographics changed in the same period, as female patients declined from 14% to 12%, White patients decreased from 20% to 16%, and African American patients increased from 51% to 58%, $p < 0.01$. Uninsured cases declined from 20% to 14%, privately insured cases declined from 34% to 24%, and Medicaid cases increased from 38% to 53%, $p < 0.001$. Meanwhile, length of stay and cost of admission did not differ significantly.

In the study period, accidental injuries declined from 29% to 25%; assault increased significantly from 60% to 66%, $p < 0.001$. Self-inflicted injuries stayed relatively stable at 3% throughout the study period. Cases involving handguns declined from 71% to 66% among accidental cases and 90% to 85% in assault cases, $p < 0.04$. Shotgun use in assault cases increased from 9% to 15% during the study period, $p < 0.001$.

Overall mortality rates did not change significantly over the same period. However, mortality associated with self-inflicted injury increased from 39% to 54%, $p = 0.006$.

Matched Analysis

On 1:1 PS-matched analysis of data from 2000 to 2009, in-hospital mortality by case was significantly higher in lenient (7.5%) versus strict (6.5%) states, $p = 0.013$. Lenient states had a proportionally higher rate of accidental (31%) and self-inflicted injury (4%) versus strict states (17% and 1.6%, respectively), $p < 0.001$. Assault-related injuries were proportionally lower in lenient (54%) versus strict (75%) states, $p < 0.001$. Military-grade weapons were more common in lenient (0.4%) versus strict (0.1%) states, $p = 0.001$. Cost (in US $) per admission was higher in strict (20,564 ± 31,700) versus lenient (18,335 ± 28,893) states, $p < 0.001$. Length of stay (in days) per admission did not differ significantly. For a tabular representation of PS-matched analysis results, see Table 3.

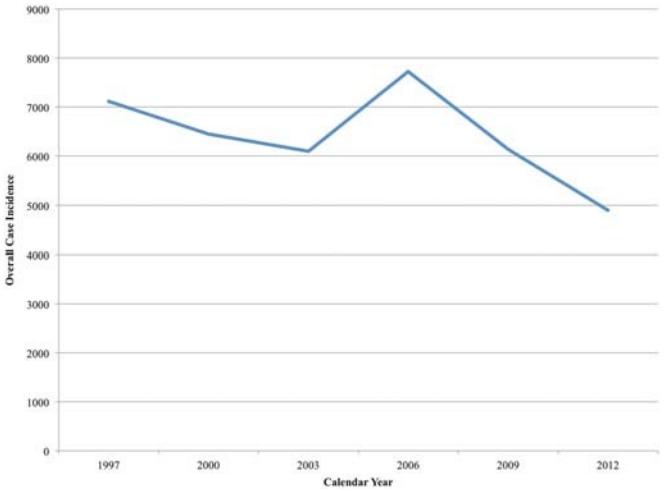

Figure 1. Overall case incidence of pediatric hospitalizations related to firearm injuries, KID's Inpatient Database, 1997–2012.

TABLE 3. Propensity Score–Matched Analysis of Pediatric Firearm Injury Characteristics, Comparing Strict Versus Lenient Gun Control States, KID 2000–2009

Category	Strict Gun Control States, n = 7,544	Lenient Gun Control States, n = 9,079	*p*
Mortality	492 / 7,544 (6.5%)	682 / 9,079 (7.5%)	0.013
Injury type			<0.001
Assault	5,645 (75%)	4,907 (54%)	<0.001
Accidental	1,299 (17%)	2,771 (31%)	<0.001
Undetermined	426 (6%)	912 (10%)	<0.001
Self-inflicted	118 (1.6%)	398 (4.4%)	<0.001
Legal intervention	55 (0.7%)	91 (1.0%)	NS
Military-grade firearm	11 (0.1%)	39 (0.4%)	0.001
Length of stay, d	5.8 ± 9.9	6.1 ± 9.4	NS
Cost of admission, US $	20,563 ± 31,700	18,335 ± 28,893	<0.001

Propensity scores were assigned using multivariate logistic regression modeling, utilizing 38 covariates on a 1:1 fixed ratio nearest neighbor method. Cases were weighted following case propensity score matching. Bivariate comparisons were performed for categorical and continuous variables, as appropriate.

NS indicates not significant at $\alpha = 0.05$.

DISCUSSION

Upon performing a trend analysis using a large, population-based database, we found that demographic characteristics of patients affected by firearms-related injuries have changed over the past two decades. Furthermore, the breakdown of firearms-related injuries has changed, with self-inflicted injuries becoming more lethal over time. These findings are significant, as this type of injury is directly associated with firearm availability.[7] Thus, a combination of legislative measures directed toward more strict regulatory standards and home-based injury prevention interventions is likely to have the most significant impact on this growing public health concern.[7] Previous studies have shown there to be a significant, strong direct correlation between gun accessibility and homicide rates; the United States has the highest rate of gun ownership, highest homicide rates, and weakest gun control laws.[5,25]

In 2010, 40% of teen suicides were committed with a firearm, and 84% of adolescents (aged 10–19 years) who were murdered were killed with a firearm.[26] Reza et al.[27] reported that 80% of school-associated firearms-related incidents involved firearms that were readily obtained from family or friends. Studies have shown that school shootings in the 1990s often involved nonautomatic guns and that most perpetrators reported a history

of being threatened or bullied.[28–30] Those who attempted suicide had also made previous attempts.[28–30] According to the Youth Suicide by Firearms Task Force, firearms are the most common way of suicide for youth across all races, sexes, and ages.[26] They reported that the suicide rate was related to firearm use and that firearms were most accessible from the home.[26] These statistics reveal the importance of creating interventions that target firearm accessibility, especially within the home.

Our matched analysis of the national experience of pediatric firearms-related injuries found that higher mortality and proportionally higher rates of accidental and self-inflicted injuries occur in lenient gun control law states when classified based on Brady Campaign criteria. Most states have minimum age limits on the purchase of firearms; thus, pediatric victims of firearms-related injury were unlikely to be the legal purchaser of the weapon. The prevalence of these specific types of pediatric firearms-related injuries is associated with the ability to access weapons.

Strict regulations for firearms purchases and ownership in one state, however, may not completely resolve a firearms problem if neighboring areas do not uphold the same standards. A recent article in the *New York Times* reported that more than two thirds of guns used in firearms-related crimes in New York and New Jersey were trafficked across state lines.[15] A similar phenomenon occurs in Chicago, where gun retailers are prohibited within city lines. Because of its location as a commercial hub, routes of firearms importation are abundant. By surveying inmates in Chicago, Cook et al.[31] found that 60% of firearms were obtained by purchase or trade, whereas many others were shared or held for other individuals. In particular, Indiana, a "D–" state by Brady Campaign criteria, is a major source for firearms used in crimes within the boundaries of Chicago and Illinois as a whole.[15] Therefore, the firearms associated with these crimes are likely passed along via unregulated channels and may be exceedingly difficult to track. In examining gun-related crime in Massachusetts, Braga et al.[10] found that the sources of 63% of recovered weapons were not available to the police. This movement of firearms is routine in regions that experience high firearms-related crime volumes that have attempted to curb violence by tightening regulations. Without a common higher standard, however, these "negative-pressure zones" will never experience a halt in the influx of weapons from elsewhere. Therefore, interventions to affect overall firearms availability, such as gun buyback programs, are likely to be the best method to reduce injuries affecting children.[32]

Increased firearm availability has also been linked to self-inflicted injury.[9] The stringency of licensing and purchasing regulations likely has a direct outcome on the its prevalence.[9,16] The introduction of permit-to-purchase laws[9] and background checks[16] have been associated with lower rates of suicide in adults. A Canadian review of the impact of legislation found that the introduction of stringent regulations had the highest impact on reducing suicides in young patients.[33] In our analysis, self-inflicted injuries occurred at a significantly higher rates in lenient states compared with strict states based on Brady Campaign criteria.

Two major regulations have been examined for their effect on firearms-related crime affecting children.[4] Stand Your Ground laws have received significant media attention in recent years. A report examining the law condemned it as a contributor to a higher rate of homicide, rather than its intended role as a self-policing method against crime.[34] Lee et al.[4] found that states with Stand Your Ground are associated with higher accidental gun-related injury rates compared with those without the law. Child Access Prevention laws have also gained attention as a method to decrease accidental injuries due to inadequately secured firearms. Examining three decades of accidental pediatric firearm injuries, Hepburn et al.[5] demonstrated that states with felony prosecution of offenders had the highest impact following the introduction of Child Access Prevention laws. Neither study, however, found that Child Access Prevention laws conferred any protection against accidental injuries in adults.[4,5]

Beyond gun control legislation alone, there are other methods by which the public can increase awareness of firearms safety and, more importantly, improve accountability for these incidents. Media portrayal of pediatric firearm injuries has been demonstrated to have a deficiency in reporting the sources of guns used in crimes.[35] This finding reflects a need to re-evaluate the manner by which we attempt to prevent firearm injuries. Assigning accountability and increasing public awareness of the availability problem are likely to be the most effective manner by which firearms regulations may become more stringent.

Our analysis also found that the percentage of African Americans within the cohort increased during the study period. This finding is in agreement with prior studies, which showed that African American children and adolescents are at significantly higher risk of firearms-related injury compared with those of other race and ethnicity.[1,36] Some other findings included a change in the type of weapon used in firearms-related injuries; the fact that handgun-related injuries are declining, whereas shotgun- and hunting rifle-related injuries are increasing in proportion, is concerning. While it remains important to address firearm availability using a blanket approach via changes in legislation, public health specialists should focus safety education and smaller-scale interventions on those demographic groups at highest risk of firearms-related injury.

Despite the rigorous conditions for analysis using PS-matched analysis, the findings of our analysis are not without limitation. First, the Brady Campaign criteria are proprietary to the Brady Campaign to Prevent Gun Violence. This classification, despite its rigorous method of grading states based on multiple levels of gun control regulatory mechanisms, has not been standardized or validated against other gun control classification methods. Second, the KID is a sample of inpatient admissions and does not include information on the long-term sequelae of injuries. For this reason, our analysis is limited to inpatient outcomes, rather than disability resulting from firearms-related injuries. Third, the KID is a retrospective database that relies heavily on the *International Classification of Diseases, Ninth Revision, Clinical Modification* coding scheme. While this provides a universal code for firearms-related injuries, it is inherently limited by the accuracy of coding and the lack of additional data resolution beyond that provided by the injury code. The KID, nevertheless, is an important and comprehensive source of clinical information regarding pediatric conditions and has been utilized in multiple prior analyses.[23,37–40]

CONCLUSIONS

When attempting to prevent pediatric firearm injury, discussion must revolve around firearm availability. The trend analysis in this cohort yielded important findings regarding the types of injury and subpopulations at highest risk. In particular, accidental and self-inflicted injuries affecting children and adolescents are likely to be associated with the strength of gun control legislation and availability. Blanket approaches to decrease availability, as well as regulations to emphasize storage safety, are likely to be the most effective preventive measures. Simultaneously, it is crucial to emphasize safety education among those demographic groups identified to be disproportionately represented in the study cohort. In today's context, where reports of firearms-related tragedies are commonplace in daily news media, the differences in legislation and routes of trafficking pose major junctions from which the discussion on injury prevention can progress.

AUTHORSHIP

J.T. contributed to the literature search, study design, data collection, data analysis, data interpretation, writing, and revision of the article. R.S.L. contributed to the literature search, data interpretation, writing, and revision of the article. L.W.B. contributed to data interpretation and revision of the article. E.A.P. contributed to the study design, data interpretation, and critical revision of the article. J.E.S. contributed to the study design, data interpretation, and critical revision of the article.

DISCLOSURE

The authors declare no conflicts of interest.

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