

## RESEARCH LETTER

# Firework injuries before and after the Michigan Fireworks Safety Act

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Approximately 10,000 firework-related injuries were treated in U.S. emergency departments (EDs) in 2019.<sup>1</sup> Although published reports use sources ranging from nationally representative data sets to single-center censuses, patient demographic factors remain consistent. Patients are 70% to 90% male and approximately 50% are under the age of 20.<sup>1-4</sup> Injuries are most common to the hands, face, and eyes and are most often burns and lacerations. Although most injuries are minor, 11% of patients require admission or transfer to a higher-level facility and critical care admissions and deaths do occur.<sup>1,2</sup> Canner et al.,<sup>2</sup> using the Nationwide Emergency Department Sample, estimated \$8 million in annual charges for firework-related ED visits.

In 2011, the Michigan State Legislature passed the Michigan Fireworks Safety Act (Act 256). Although entitled a safety act, the law allows the sale of consumer fireworks (i.e., fireworks that leave the ground), including bottle rockets, roman candles, and aerial spinners.<sup>5</sup> Previously, only on-ground fireworks (called low-impact fireworks) and novelty items (e.g., party poppers) were permitted. The possession of consumer fireworks prior to the safety act was illegal, although penalties were minor and were seldom enforced. Many Michigan residents simply went to neighboring states with more lenient firework laws to purchase consumer fireworks. The new law aimed to recover tax revenue lost to these nearby states and went into effect January 1, 2012. The aim of this project is to characterize firework injuries presenting to an adult and pediatric Level I trauma center from 2005 to 2018 to elucidate any temporal relationships between the sale of larger, more powerful fireworks and the number and severity of firework injuries.

The larger, more powerful fireworks now legal in Michigan cause disproportionately more severe and permanent injuries than other firework types, especially injuries to the hands and eyes and

traumatic brain injuries.<sup>3</sup> In a nationally representative sample, as more states allowed the sale of consumer fireworks the incidence of firework injuries increased modestly, but injuries became more severe. Injuries requiring hospital admission grew from 29% in 2006 to 50% in 2012 with a corresponding length-of-stay increase from 3.1 days to 7.4 days.<sup>6</sup> State-level examinations have found similar results including escalated health care costs and insurance payouts for property damage.<sup>7,8</sup> In the years that the Michigan law has been in effect, there have been no published studies of firework injuries in the state. The law has been fiscally beneficial to the state; sellers' licenses and firework sales have generated more than \$18 million as of mid-2017.<sup>9</sup> However, this increased revenue may come at the cost of more or more severe injuries to Michigan residents.

We searched ED encounters from January 1, 2005, through December 31, 2018, to identify firework injuries using ICD-9/10 codes (E923.0 and W39, respectively) and our institution's Electronic Medical Record Search Engine (EMERSE), which permits Boolean searches of written portions of medical records, such as ED notes.<sup>10</sup> Exclusion criteria were (1) injuries occurring outside of Michigan, (2) nontraumatic firework injury (e.g., ingestion of fireworks), (3) injuries at professional firework shows (regulations regarding use of professional-grade fireworks were not changed by the law), or (4) insufficient data available to complete data abstraction table. This study was approved by our institutional review board.

Patient and injury factors were compared by date of injury (January 1, 2005–December 31, 2011 vs January 1, 2012–December 31, 2018). Continuous variables (age and hospital length of stay) were checked for normality and compared using parametric or non-parametric t-tests as appropriate. Categorical variables (all others) were compared using chi-square or Fisher's exact test as appropriate. Significance was set at  $p < 0.05$ .

Our search yielded 619 unique patients. In 237 cases the word "firework" or "firecracker" was used in the ED note but

**TABLE 1** Demographic, fireworks, and injury factors before and after the Michigan Firework Safety Act<sup>a</sup>

	Before law change, Jan 1, 2005–Dec 31, 2011	After law change, Jan 1, 2012–Dec 31, 2018	p-value
Number of cases	81	160	
Number of cases per year			
Mean ( $\pm$ SD)	12 ( $\pm$ 2.9)	23 ( $\pm$ 4.3)	0.0002 <sup>*</sup>
Median (range)	11 (9–18)	22 (18–30)	
Male, n (%)	67 (83)	132 (83)	0.95
Age (y)			
Mean ( $\pm$ SD)	23 ( $\pm$ 15.7)	26 ( $\pm$ 16.6)	0.16
Median (range)	20 (1–63)	25 (0–76)	
Race			
Black	11 (14)	25 (16)	0.93
White	64 (79)	120 (75)	
Other	6 (7)	14 (9)	
Unknown	0	1 (1)	
Firework type <sup>b</sup>			
Consumer fireworks	43 (53)	100 (66)	0.62
Low-impact fireworks	17 (21)	23 (14)	
Novelties	1 (1)	3 (2)	
Illegal fireworks	6 (7)	10 (6)	
Homemade fireworks	8 (10)	10 (6)	
Unknown	6 (7)	14 (6)	
Specific firework <sup>c</sup>			
Mortar	20 (33)	74 (59)	0.02 <sup>*</sup>
Bottle rocket/Roman candle	13 (21)	15 (12)	
Firecracker	10 (16)	11 (9)	
Sparkler	14 (23)	19 (15)	
Other low-impact fireworks or novelties	4 (7)	8 (6)	
Was patient user of firework?			
No	16 (20)	40 (25)	0.36
Yes	63 (78)	116 (73)	
Unknown <sup>d</sup>	2 (2)	4 (3)	
Transfer			
No	26 (32)	45 (28)	0.54
Yes	55 (68)	115 (72)	
Injury type <sup>e</sup>			
Burn	45 (56)	95 (59)	0.57
Laceration	14 (17)	37 (23)	0.29
Traumatic amputation	6 (7)	27 (17)	0.04 <sup>*</sup>
Foreign body	9 (11)	11 (7)	0.26
Fracture	15 (19)	19 (12)	0.16
Contusion	5 (6)	15 (9)	0.39
Blast injury	11 (14)	20 (13)	0.81
Corneal abrasion and/or burn	12 (15)	21 (13)	0.72
Globe rupture	11 (14)	11 (7)	0.09
Other	8 (10)	23 (14)	0.32
Injury area <sup>e</sup>			

(Continues)

Table 1 (Continued)

	Before law change, Jan 1, 2005–Dec 31, 2011	After law change, Jan 1, 2012–Dec 31, 2018	p-value
Eye	29 (36)	51 (32)	0.54
Head/skull/brain	6 (7)	13 (8)	0.85
Face	32 (40)	47 (30)	0.11
Digit/hand	31 (38)	77 (48)	0.15
Other upper extremity	12 (15)	21 (13)	0.72
Trunk	7 (9)	20 (13)	0.37
Lower extremity	4 (5)	15 (9)	0.23
Surgery required			
No	50 (62)	105 (66)	0.55
Yes	31 (38)	55 (34)	
ED disposition			
Discharged	45 (56)	93 (58)	0.95
Admitted	34 (42)	64 (40)	
Other	1 (1)	2 (1)	
Length of stay <sup>f</sup>			
Mean ( $\pm$ SD)	4 ( $\pm$ 5.1)	5 ( $\pm$ 7.3)	0.45
Median (range)	2 (1–21)	3 (1–55)	

Note: Data are reported as *n* (%) unless otherwise reported.

<sup>a</sup>Law went into effect January 1, 2012.

<sup>b</sup>Consumer fireworks: aeriels, bottle/sky rockets, firecrackers, helicopters/spinners, missile-type rockets/mortars, Roman candles, shell devices (single or reloadable). Low-impact fireworks: smoke devices, sparklers, sparkling wheel devices. Novelties: party poppers, snakes, snappers. Federally regulated illegal fireworks: cherry bombs, m80's.

<sup>c</sup>Excluding illegal, homemade, and unknown fireworks.

<sup>d</sup>p-value calculated after removal of missing values.

<sup>e</sup>Patients can have more than one type of injury and more than one injured area.

<sup>f</sup>Among patients who were admitted.

\**p* < 0.05.

there was no firework-related injury (e.g., patient reported visual distortions that looked like fireworks). Injuries in 109 cases were in the setting of watching fireworks, but were not caused by fireworks, including chest pain, falls, and assaults. In 17 cases, fireworks caused nontraumatic harm including asthma attacks and poisoning secondary to ingestion. Eleven patients were transferred from out of state. One patient was injured by flaming debris at a professional fireworks show. Two excluded patients presented to the ED for fractures and also had recent firework burns for which medical treatment was neither required nor sought. Finally, one patient was seeking pain medication citing a past firework injury. A total of 241 patient encounters were included in this analysis. There were no duplicate patients. The majority of injuries (62%) occurred during a 2-week period before and after Independence Day. Another 19% of injuries occurred in June or July outside of this 2-week period. Patients were disproportionately male (83%; Table 1) Injured patients ranged in age from 2 months to 76 years, with a mean of 25 years; 40% of patients were under age 18. The age groups with the highest proportion of injuries were patients under 5 years and those age 10 to 14 years.

The number of firework-related encounters from 2005 to 2011 was 81 compared to 160 from 2012 to 2018. The number of all-cause ED encounters at our institution increased over this time period as well. The annual incidence rate of firework injuries presenting to the ED before the law change was 14.3 per 100,000; after the law change it was 21.0 per 100,000 (*p* = 0.001). Consumer fireworks caused the most injuries, whether or not their use was legal at that time (Table 1). In both time periods, mortars (which include missile-type rockets, single-tube devices with report, and reloadable shell devices) were the most common cause of injury followed by sparklers, bottle rockets/roman candles, and firecrackers, respectively. However, after the law change the proportion of injuries caused by mortars was significantly higher (59% vs 33%; *p* = 0.02). There was a corresponding significant increase in traumatic amputation postlaw (7% vs 17%; *p* = 0.04). There were no differences in other injury types or injury location. At both times, over half of participants experienced burns, with lacerations and fractures also common.

Digits/hands, face, and eyes were injured most frequently. There were no differences in other injury characteristics based on time period. Both before and after the law, the patient was most often the

firework user (74%). Seventy percent of patients were transferred from another facility. Surgical treatment was required in 36% of cases. The patient was admitted 41% of the time and mean ( $\pm$ SD) length of stay was 4.6 ( $\pm$ 6.6) days (range = 1–55 days). Because of transfers some patients did not receive follow-up treatment at our institution, but we were able to determine whether or not persistent disability was experienced for the majority of patients. Most patients (71%) had no apparent lasting physical sequela from their injuries. Among the patients with long-term disability, six patients were treated with unilateral enucleation; an additional five patients were left with unilateral light or motion perception only and one patient had bilateral light perception only. Six patients had metacarpal-level or proximal amputations. One patient experienced a traumatic brain injury when he was hit in the face with a mortar resulting in persistent cognitive deficits. There were no fatalities in our cohort, although one patient was injured by an explosion of homemade fireworks that resulted in a fatality at the scene.

Our study shows that after the Michigan Fireworks Safety Act, the number of patients presenting to our institution's ED with firework-related injuries increased significantly. Additionally, a significantly higher proportion of injuries were caused by mortars and traumatic amputations increased significantly. Our data also show that consumer fireworks injured patients even when they were illegal in Michigan, indicating that repeal of the law alone will not eliminate firework injuries. Our results are analogous to other analyses of state firework legislation. In 2002, Minnesota legalized the use of low-impact fireworks; previously only novelties had been permitted. Statewide ED records showed an over 100% increase in the number of firework-related injuries.<sup>8</sup> Likewise, in 2016, West Virginia legalized all consumer fireworks. Postlaw the injury rate increased 39%.<sup>4</sup>

This study is subject to the limitations of all retrospective studies, including missed cases and incomplete medical record data. This study is also of a single center, which may limit its generalizability. Nationally representative databases such as the National Trauma Databank and the Nationwide Emergency Department Sample stratify data only by region, not by state, so we could not use them for this examination of a single state law. However, our institution is both an adult and a pediatric Level I trauma center and thus receives cases from far outside its regular catchment area. We are likely, however, underestimating the number of less severe injuries that may be treated at community hospital EDs or urgent care centers. It is also possible that the increase in injuries was not related to the Michigan law, but was in response to other societal trends or factors. However, according to nationally representative samples there was no significant change in the rate of firework injuries during the study period.<sup>1,2</sup>

The debates of firework use in Michigan have taken place largely without evidence. Our analysis provides necessary data to inform policy discussions, namely, that after loosening restrictions firework injuries increased at one Level I trauma center and these injuries were more often caused by newly legal fireworks. Additional

research, including a statewide investigation and injury-prevention messaging, would further support discussion of the law's merits.

## CONFLICT OF INTEREST

The authors have no potential conflicts to disclose.

## AUTHOR CONTRIBUTIONS

Melissa J. Shauver: study concept and design, acquisition of the data, analysis and interpretation of the data, and drafting of the manuscript. Kevin C. Chung: critical revision of the manuscript for important intellectual content.

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