



Original Contribution

Fireworks type, injury pattern, and permanent impairment following severe fireworks-related injuries



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ABSTRACT

Background: There is a paucity of clinical data on severe fireworks-related injuries, and the relationship between firework types, injury patterns, and magnitude of impairment is not well understood. Our objective was to describe the relationship between fireworks type, injury patterns, and impairment.

Methods: Retrospective case series (2005–2015) of patients who sustained consumer fireworks-related injuries requiring hospital admission and/or an operation at a Level 1 Trauma/Burn Center. Fireworks types, injury patterns (body region, injury type), operation, and permanent impairment were examined.

Results: Data from 294 patients 1 to 61 years of age (mean 24 years) were examined. The majority (90%) were male. 119 (40%) patients were admitted who did not undergo surgery, 163 (55%) patients required both admission and surgery, and 12 (5%) patients underwent outpatient surgery. The greatest proportion of injuries was related to shells/mortars (39%). There were proportionally more rocket injuries in children (44%), more homemade firework injuries in teens (34%), and more shell/mortar injuries in adults (86%). Brain, face, and hand injuries were disproportionately represented in the shells/mortars group. Seventy percent of globe-injured patients experienced partial or complete permanent vision loss. Thirty-seven percent of hand-injured patients required at least one partial or whole finger/hand amputation. The greatest proportion of eye and hand injuries resulting in permanent impairment was in the shells/mortars group, followed by homemade fireworks. Two patients died. **Conclusions:** Severe fireworks-related injuries from homemade fireworks and shells/mortars have specific injury patterns. Shells/mortars disproportionately cause permanent impairment from eye and hand injury.

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1. Introduction

The United States Consumer Product Safety Commission (CPSC) estimates approximately 10,500 individuals (3.3 per 100,000) were treated in hospital emergency departments for fireworks-related injuries in 2014, a rate that has not significantly changed since 1999 [1]. Federal law permits consumer fireworks sale and sets type-specific size limitations; however, state and local authorities may further regulate their utilization.

Prior studies have found fireworks-related injuries commonly result from legal fireworks and disproportionately occur in children and males [1–5]. Earlier work documented injury to both active users of fireworks

and bystanders and reported high rates of fireworks misuse and mal-function [1,2,4–6]. The majority of injuries involved the hands or face, were burns, and were treated and discharged directly from the Emergency Department (ED) [1–5]. However, national database reviews have been limited by broad data elements with a large number of minor injuries obscuring severe injury patterns [1–3,7].

The relationship between fireworks types and specific injury patterns has not been well described. In particular, there remains a paucity of clinical data on severe fireworks-related injuries. Existing reports on severe injuries are small and do not provide detailed injury patterns [6, 8]. One case-control study specifically evaluated risk factors for fireworks-related injuries and found that while most injuries were from federally-legal fireworks, most hospitalizations were due to federally-illegal fireworks; homemade types in particular were associated with the highest hospitalization rate [4]. Two national database reviews found severe injuries requiring hospitalization were more likely due to illegal

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fireworks than other fireworks types [2,7]. However, inconsistent grouping of fireworks types makes comparisons across studies difficult.

Understanding the relationship between fireworks type and injury severity is important to clinicians, legislators and public health practitioners. Using data from a large Level 1 Trauma/Burn Center, we aimed to describe the relationship between fireworks type, injury patterns, and permanent impairment among patients with severe fireworks-related injuries.

2. Methods

2.1. Study population

This case series was approved by the Institutional Review Board of the participating site. Patients of all ages who sustained fireworks-related injuries were identified from our hospital's Trauma Registry by searching for Internal Classification of Diseases, Ninth Revision (ICD-9) external cause of injury code E923 (accident caused by explosive material not otherwise specified). Patients were eligible if they sustained an injury due to fireworks requiring either inpatient admission and/or an operation between July 2005 and September 2015 ($n = 294$). Patients injured at professional fireworks displays were excluded ($n = 5$). Minor injuries, defined as those treated non-operatively or in the outpatient setting only, were excluded ($n = 98$).

Fireworks type (homemade, shells/mortars, rockets, firecrackers, Roman candles, sparklers, and unknown) was abstracted from the medical record, as reported by the patient. We also abstracted demographic information, (gender, age, race), fireworks use behavior (active user or bystander), disposition from the ED (floor admission, intensive care unit (ICU) admission, non-admit operating room (OR) only), and number of operations.

2.2. Outcomes

The two main outcomes were injury patterns (combination of body region and injury type) and permanent impairment.

Specific injury types (soft-tissue, fractures, burns) were recorded for each body region (face, hand, arm, trunk, leg). For injuries affecting more than one body region, only injuries to body regions severe enough to warrant hospital admission or surgery were recorded; the exception was globe injuries, where all were recorded regardless of severity. Within body regions, operative subcategories captured injuries necessitating surgery. Injury types and body regions were not mutually exclusive. Penetrating trunk injuries were recorded separately from trunk soft-tissue injuries. A face or limb with multiple fractures was counted as one fracture. Brain injuries were defined as those with intracranial hemorrhage.

Impairment ratings for eye and hand injuries were calculated as percent whole person impairment (WPI) according to the *American Medical Association Guides to the Evaluation of Permanent Impairment* [9]. Visual function was calculated using visual acuity and visual field measurements documented by formal ophthalmologic examination, and enucleations were documented. Patients with vision loss were then categorized as less or $>50\%$ WPI. Hand impairment was calculated based on distribution and level of finger/hand amputation(s). Patients with finger/hand amputation(s) were then categorized as less or $>20\%$ WPI. Impairment ratings represented minimum impairment as patients may have had additional injuries; the two WPI ratings were not mutually exclusive and were not combined.

2.3. Statistical analysis

We examined demographic characteristics, fireworks use behavior, admission disposition, and number of operations to calculate proportions and means by fireworks type. To assess the amount of surgical care required to treat injuries, we examined the relationship between

fireworks type and number of operations. We assessed permanent impairment to eyes (visual defect) and hands (amputation distribution and level) by fireworks type, classified into four subcategories (no injury, injury without impairment, low impairment, and high impairment).

3. Results

The study population included 294 patients 1 to 61 years of age (mean 24 years) with one-third <18 years. The majority of patients (90%) were male. There were 119 patients (40%) admitted who did not undergo surgery, 163 patients (55%) who required both admission and surgery, and 12 patients (5%) who underwent outpatient surgery. There were two deaths.

3.1. Injury patterns by fireworks types

The greatest proportion of injuries was related to shells/mortars (39%; Table 1). The proportion of injuries related to different fireworks types varied by age, with proportionally more rocket injuries in children, more homemade fireworks injuries in teens, and more shell/mortar injuries in adults (Table 2). Bystanders were more frequently injured by aerial-type fireworks (shells/mortars, rockets, Roman candles) than by non-aerial fireworks (55%) (Table 2). Number of operations ranged 0 to 15 (mean 1.6); the greatest proportion of surgeries was observed among the shells/mortars group (Table 2).

Soft-tissue injuries were mostly blast injuries and avulsions. Among burn injuries, most were non-operative (57/60 face burns, 69/71 hand burns, 36/41 arm burns, 23/27 trunk burns, and 21/30 leg burns). Eight out of ten penetrating trunk injuries were due to homemade fireworks, and half of penetrating trunk injuries caused internal organ damage. Brain, face, and hand injuries were disproportionately represented in the shells/mortars group (Table 3). Face injuries (including superficial and partial thickness flash burns) most frequently occurred with both homemade fireworks and shells/mortars, whereas more severe operative face injuries (including fractures, deep burns, and soft-tissue avulsions) more frequently occurred with shells/mortars. Globe injuries, and particularly those requiring enucleation, most frequently occurred with projectile fireworks (i.e., shells/mortars and rockets). Arm, trunk, and leg injuries requiring surgery, though infrequent, most commonly occurred with homemade fireworks. Firecrackers caused a larger proportion of leg injuries than other types of injuries (Table 3).

3.2. Permanent impairment by fireworks types

Twenty-one percent of patients sustained globe injuries. Over two-thirds (70%) of globe-injured patients experienced partial or complete permanent vision loss, and 18% of them underwent enucleation (Table 4). WPI ranged 1% to 77%, with unilateral enucleation resulting in 50% to 77%. Sixty-one percent of patients sustained hand injuries. Over one-third (37%) of hand-injured patients required at least one partial or whole finger/hand amputation (Table 4). There were six complete hand amputations. Impairment ratings ranged from 2% to 4% for amputation of one fingertip to 54% for complete hand amputation. Shells/mortars, followed by homemade fireworks, caused the greatest proportion of eye and hand injuries resulting in permanent impairment (Table 4).

4. Discussion

Data from this study indicate that specific severe injury patterns from fireworks vary by fireworks type. Shells/mortars caused the highest proportion of severe injuries, disproportionately injuring the face, brain and hands. Shells/mortars resulted in more permanent impairment than other fireworks types as a result of eye and hand injuries.

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