Using an Algorithm for Reconstruction of Low-energy Blast Injuries of the Hand

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Abstract

Background: Low-energy blast injuries caused by fireworks and other small explosives are a significant source of hand trauma resulting in fractures, amputations, and soft-tissue defects. In this study, we aimed to present a comprehensive clinical algorithm for managing these injuries and to share our experience in treating hand trauma resulting from low-energy blasts. **Materials and Methods:** A retrospective study was conducted on 37 patients who presented to the emergency services at two university hospitals between 2015 and 2018 with isolated hand trauma due to low-energy blasts. Upon arrival, the patients underwent tetanus prophylaxis and were stabilized before evaluation. All patients underwent surgery on the same day as the injury. Demographics, type of explosives, and reason for the explosion were noted, and treatment modalities were meticulously documented. **Results:** Of the 37 patients, 29 were injured by firecrackers and 8 by fireworks. Among the patients, 7 presented with total amputations, 3 had circulation problems before the operation, and 24 required bone fixation. Soft-tissue reconstruction was necessary in 30 patients, and vacuum-assisted closure therapy, skin grafting, or flap reconstruction was performed in seven patients. Delayed complications were observed in 12 patients during the postoperative period. **Conclusion:** Low-energy blast injuries of the hand require a multidisciplinary treatment approach. Our clinical algorithm provides an efficient treatment modality that emphasizes early exploration and aggressive debridement. We recommend managing soft-tissue defects by approximating existing tissues without tension. Furthermore, our findings suggest that legal and sales regulations are effective in reducing firework-related hand injuries, highlighting the importance of their consideration.

Keywords: Blast injury, hand surgery, reconstruction

Introduction

Low-energy blast injuries are predominantly associated with fireworks such as sparklers and small explosive devices containing gunpowder such as firecrackers. These explosives are primarily used for their visual and auditory effects during celebrations or children's recreational activities. The most frequently affected anatomical regions are the eyes and upper extremities.[1,2] Low-energy blast injuries result from two distinct mechanisms: thermal injury, which leads to burns, and blast injury, which is characterized by shock waves causing fractures, amputations, and soft-tissue defects.[3-5] The complexities arising from these consequences require a meticulous assessment and comprehensive management.

In this study, we aimed to present our clinical algorithm and share our practical experience in the management of low-energy blast injuries. This algorithm offers a systematic and structured approach to the treatment of these injuries, ensuring a more effective and efficient clinical outcome. We believe that a deeper understanding of low-energy blast injuries is essential for both professional colleagues and the broader medical community.

Materials and Methods

A retrospective study was conducted on 37 patients who presented to the emergency services of our hospitals between 2015 and 2018 with isolated hand trauma due to low-energy

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blasts. This study was approved by the ethics committee of our hospital (Number: 24/153). All patients signed an informed consent form. Of these patients, 12 were female and 25 were male. Inclusion criteria included patients presenting with hand injuries due to low-energy blast events with both mild and severe soft-tissue damage commonly associated with explosives such as fireworks or volcanoes used for visual and auditory effects. Conversely, the exclusion criteria pertained to injuries resulting from high-energy explosions, patients with coexisting medical conditions such as hypertension and diabetes mellitus, and individuals sustaining low-energy blast injuries in anatomical regions other than the hand. The fundamental distinction between low-energy and high-energy injuries is rooted in the disparity in the energy levels associated with the events. Low-energy injuries are often attributed to explosives employed for visual and auditory effects in celebrations or children's games, whereas high-energy injuries result from more potent explosives. On arrival, patients with low-energy injuries were first stabilized in terms of vital signs and then evaluated in the emergency room. The injured hands were irrigated with saline following tetanus prophylaxis (Tdap vaccine + 250 IU Tetanus immunoglobulin). All patients underwent surgery on the same day as the injury. After ensuring appropriate conditions, patients underwent motor examination, sensory examination, and circulation examination. The treatments were shaped according to the algorithm used in our clinical practice [Figure 1]. In cases of total or subtotal amputations that restricted circulation, replantation/revascularization was attempted first, and amputation was performed if unsuccessful. In cases where circulation was natural, the presence of fractures was evaluated first, followed by an assessment of the condition of soft tissue after fixation of the bone. The treatment was then performed using the appropriate reconstruction option [Figures 2 and 3]. In cases of dirty injuries, temporary wound dressings were applied until the wound was clean. Depending on the soft-tissue condition, secondary healing, vacuum-assisted closure (VAC) therapy, or repair with a flap or graft may be considered. During the postoperative period, all wounds were considered contaminated and broad-spectrum antibiotic therapy with parenteral 1 g ampicillin–sulbactam and 1 g metronidazole per day was administered for prophylaxis. The patient demographics, type of explosives, and reason for the explosion were noted. The type of injury and anatomical site, as well as treatment modalities, were documented. Data analysis was performed using SPSS (IBM SPSS Statistics for Mac, Version 21.0, IBM Corp., LA, USA). The variable and normality distributions were checked using the Kolmogorov–Smirnov test. Mean,

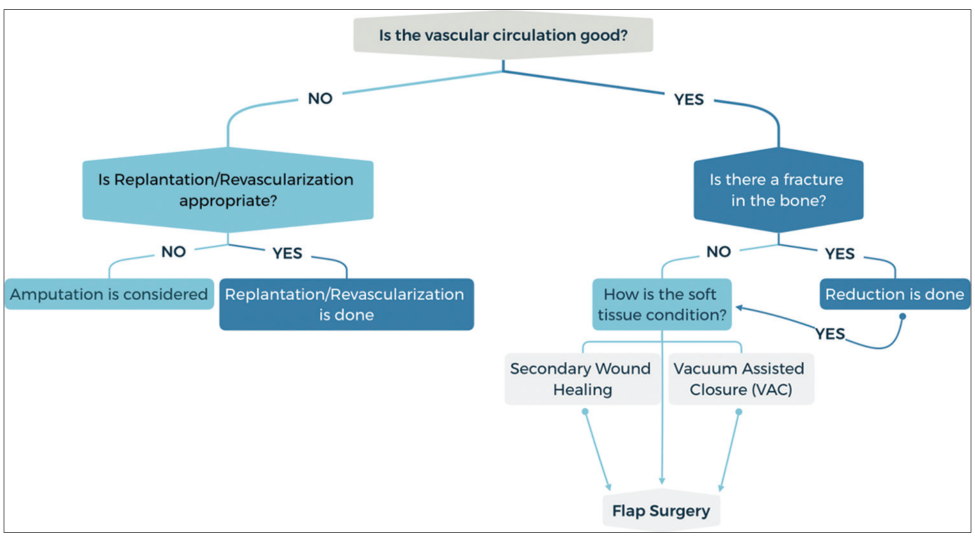

Figure 1: The algorithm that we use in our clinical practice

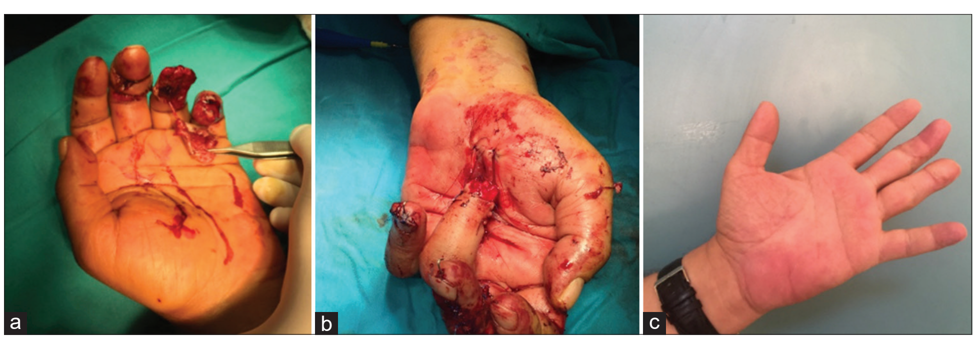

Figure 2: Injury resulting from low energy blast (a) There was a fracture in the distal phalanx of the third finger and volar defects in the fourth and fifth fingers (b) The defect in the fourth finger was reconstructed using a thenar flap (c) Postoperative 4th-month image

standard deviation, median, and interquartile range values were used for the descriptive statistics analysis.

Results

A total of 37 patients were included in the study, consisting of 12 female and 25 male patients. The mean age of the patients was 29.74 ± 18.14 years (range: 8–75). Among the patients, 29 were injured by firecrackers, while 8 were injured by fireworks [Table 1]. The mean follow-up time was 13.7 months (range: 8–24) [Table 2]. Seven patients presented with total amputations and three patients had circulation problems before the operation. Five of these patients underwent stump closure because of irreplantable amputated tissue, while 24 required bone fixation. Among them, 20 underwent bone fixation with k-wires, and 4 underwent bone fixation with plates. Soft-tissue reconstruction was necessary for 30 patients, 4 of whom were left to heal by secondary intention. VAC therapy was administered to five patients, while two patients underwent full-thickness skin grafting. The remaining 19 patients underwent flap reconstruction. The most commonly preferred flaps were the local and pedicled flaps, which were used in 16 patients. Free flaps were used in patients with surrounding tissue injuries. Delayed complications were observed in 12 patients during the postoperative period. Stiffness in the distal interphalangeal joint was observed in seven patients, scar contracture in the web space was observed in three patients, mallet finger deformities were observed in one patient, and paresthesia continuing after 6 months was observed in one patient.

Discussion

Low-energy explosives, such as fireworks and torpedoes, are commonly used for recreational purposes and differ from high-energy explosives in their use of simple chemicals. These explosives can cause damage through thermal effects and bursts of shockwaves, with the latter being more likely to result in fractures, dislocations, or amputations.[5-7] Injuries typically affect different regions of the hand simultaneously, necessitating a range of treatment and reconstruction methods tailored to each patient's specific presentation.

Low-energy blast injuries frequently affect the eyes and upper limbs, with hand injuries occurring either in isolation or affecting both hands.[8,9] In our study, we observed that the nondominant hand was more commonly affected by the dominant hand holding the firework, which is consistent

Table 1: The treatment modalities and complications of the patients and their subtypes

Treatment methods/ complications	Subtypes of treatment methods or complications
Replantation/ revascularization (*n*=10)	Amputation (*n*=5)
	Revascularization (*n*=3)
	Replantation (*n*=2)
Bone fixation (*n*=24)	K-wire (*n*=20)
	Plate (*n*=4)
Soft-tissue reconstruction (*n*=30)	Secondary healing (*n*=4)
	VAC (*n*=5)
	Graft (*n*=2)
	Flap (*n*=19)
	Local flap (*n*=10)
	Pedicled flap (*n*=6)
	Free flap (*n*=3)
Complications (*n*=12)	Stiffness in the distal interphalangeal joint (*n*=7)
	Scar contracture in the
	First web space (*n*=3)
	Mallet finger deformity (1)
	Ongoing Paresthesia in the 6th-month follow-up (1)
Affected areas and trauma severity	Metacarpal bone (*n*=20)
	Severe (12)
	Mild (8)
	Proximal phalanx (*n*=10)
	Severe (6)
	Mild (4)
	Middle phalanx (*n*=4)
	Severe (1)
	Mild (3)
	Distal phalanx (*n*=3)
	Severe (2)
	Mild (1)
Location and size of defects requiring flaps (cm)	Metacarpal bone (3.2×4.1)
	Proximal phalanx (2.2×2.3)
	Middle phalanx (1.7×1.9)
Affected bones and fracture features	Metacarpal bone (10 Tr, 3 Ob, 2 Sp)
	Proximal phalanx (3 Tr, 3 Ob)
	Middle phalanx (2 Tr, 1 Sp)

Severe: These injuries may include fractures, dislocations, amputations, severe lacerations, nerve damage, or extensive soft-tissue injuries, Mild: This refers to injuries that are less severe and typically do not involve significant structural damage to the hands. Tr: Transverse, Ob: Oblique, Sp: Spiral, VAC: Vacuum-assisted closure

Figure 3: Injury resulting from low energy blast (a) There was a defect in the second finger (b) The defect in the second finger was reconstructed using a free venous flap (c) Postoperative 4th-month image

Table 2: Descriptive characteristics of the patients in the study

Descriptive characteristics of the patients in the study	
The number of patients in the study	12 female, 25 male
Age, mean±SD (maximum–minimum)	29.74±18.14 (75–8)
Type of injury	29 firecrackers, 8 fireworks
Mean follow-up time (months)	13.7 (8–24)

SD: Standard deviation

with the findings in the literature.[10] Puri *et al*. have reported in their 10-year study that the nondominant hand was more frequently injured. Furthermore, the majority of our patients were male and younger than 30 years, with a peak age of occurrence of 10–14 years old.[8-11] In the reported cases, the distal phalanx was identified as the most commonly affected part of the finger.[8,10,12] Low-energy blast hand injuries often occur on significant days such as New Year's Eve or national holidays.[2,13]

In our study, we found that only one patient sustained injuries from flares on New Year's Eve, while most injuries were caused by firecrackers, which is the primary cause of firework-related hand injuries reported in the literature. Our patients typically obtained firecrackers from local markets; however, studies have shown that legal regulations and restrictions on fireworks purchasing can help reduce the incidence of such injuries.[8,13,14] Health-care committees should be encouraged to implement such measures, particularly to prevent firework-related injuries among children. Furthermore, legal regulations pertaining to explosives or educating the community will contribute to the reduction of injuries.

Low-energy blast injuries to the hand can cause burns, soft-tissue contusions, lacerations, fractures, and amputations simultaneously owing to the multimechanistic nature of the injury. Therefore, each case requires individualized treatment. We advocate early aggressive debridement and instead recommend managing soft-tissue defects by approximating existing tissues without tension. Furthermore, legal and sales regulations have been shown to decrease firework-related hand injuries and should be considered.

In this study, we described our approach for managing patients with low-energy blast injuries according to our clinical algorithm. Hand injuries, caused by low-energy blasts, high-energy trauma, or other mechanisms, require a systematic and structured approach to ensure effective and efficient clinical outcomes. The following literature review provides insights into algorithmic approaches for the management of hand injuries encompassing a wide range of traumatic scenarios. Gilron and Weaver discussed blast injuries, including barotrauma, blast injuries, and tympanic membrane perforation, emphasizing the need for a comprehensive understanding of the mechanisms and consequences of blast injuries.[15] Ritenour and Baskin focused on the diagnosis and treatment of primary blast injuries, providing an update on the management and screening of primary blast injuries.[16] Guermazi *et al*. discussed the imaging of blast injuries to the lower extremities, emphasizing the role of diagnostic imaging in assessing blast-related lower extremity injuries.[17] The importance of rapid diagnosis and treatment, especially for blast injuries, has been emphasized. The aforementioned publications also advocate the necessity of an applicable algorithm for prompt and accurate treatment. Our study was based on these findings. We emphasize the importance of evaluating finger circulation as soon as possible and performing early exploration if there is any doubt. Our algorithm reflects the term "amputation" specifically referring to finger amputations. We explained that K-wires are often preferred over plates for bone fixation due to the latter's requirement for wider dissection and higher morbidity. Soft-tissue reconstruction can be approached using a wide spectrum of methods, from secondary healing to free flaps. Unless critical structures such as blood vessels, nerves, or bones are exposed, reconstruction may be delayed until a swap culture is obtained from the wound and cleaned. During dissection, if there were gaps in the nerve or tendon, repair was performed with nerve/tendon grafts before proceeding with soft-tissue reconstruction. This situation was frequently encountered, especially in cases of partial injuries. During this period, we frequently used VAC therapy, which has become more commonly used in the last two decades. Although local flaps are generally preferred in flap surgery, free flap surgery may also be used to maintain tissue integrity. After treatment, patients may encounter complications such as stiffness in the distal interphalangeal joint, scar contracture, hypoesthesia, and restricted movement and may undergo additional surgeries. Especially from a medicolegal perspective, it is necessary to specify these conditions in informed consent, and providing information to patients verbally would also be beneficial. To minimize complications during the postoperative period, it is essential to have an appropriate physical therapy protocol and regular patient follow-up. The majority of complications require surgical treatment rather than conservative management. Joint arthrodesis or mallet finger surgery are commonly used methods in the treatment of complications. It has been observed that fireworks injuries, particularly in children, are common in our patient database. To minimize this situation, there should be serious monitoring and deterrent penalties for selling fireworks to children."

Our study had some limitations, such as its retrospective design and small sample size. Furthermore, patients with comorbidities were not included, and postoperative range of motion was not evaluated.

Although high-energy traumas are catastrophic, low-energy blast injuries are difficult to treat. Low-energy blast injuries to the hand require a multidisciplinary treatment approach. Our clinical algorithm provides an appropriate and efficient treatment modality. Our algorithm can be used as a template. Studies can be further enriched by working with templates that include logical sequences. We believe that our study contributes to future research on this topic.

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Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Read DJ, Bradbury R, Yeboah E. Firework-related injury in the top end: A 16-year review. ANZ J Surg 2017;87:1030-4.
2. Matheron AS, Hendriks S, Facca S, Liverneaux PA. Hand injuries due to firework devices: A series of 58 cases. Chir Main 2014;33:124-9.
3. Smith GA, Knapp JF, Barnett TM, Shields BJ. The rockets' red glare, the bombs bursting in air: Fireworks-related injuries to children. Pediatrics 1996;98:1-9.
4. Wightman JM, Gladish SL. Explosions and blast injuries. Ann Emerg Med 2001;37:664-78.
5. Al-Qattan MM, Al-Tamimi AS. Localized hand burns with or without concurrent blast injuries from fireworks. Burns 2009;35:425-9.
6. Kankaya Y, Oruç M, Uysal A, Koçer U. Multiple closed flexor tendon avulsions from their insertions by a high-energy explosion. J Hand Surg Br 2006;31:663-4.
7. Karakol P, Sezgiç M, Tatar BE, Gelbal C, Uslu C. The use of dorsoradial forearm flap for the treatment of dorsal hand defect. J Surg Case Rep 2020;2020:rjaa153.
8. Moore JX, McGwin G Jr., Griffin RL. The epidemiology of firework-related injuries in the United States: 2000-2010. Injury 2014;45:1704-9.
9. Wang C, Zhao R, Du WL, Ning FG, Zhang GA. Firework injuries at a major trauma and burn center: A five-year prospective study. Burns 2014;40:305-10.
10. Puri V, Mahendru S, Rana R, Deshpande M. Firework injuries: A ten-year study. J Plast Reconstr Aesthet Surg 2009;62:1103-11.
11. Vassilia K, Eleni P, Dimitrios T. Firework-related childhood injuries in Greece: A national problem. Burns 2004;30:151-3.
12. Yasmeh S, Trasolini NA, Li WY, Yang H, Ghiassi A. Firework-related hand injuries: A novel classification system. Am J Emerg Med 2018;36:897-9.
13. Sheller JP, Muchardt O, Jønsson B, Mikkelsen MB. Burn injuries caused by fireworks: Effect of prophylaxis. Burns 1995;21:50-3.
14. Foged T, Lauritsen J, Ipsen T. Firework injuries in Denmark in the period 1995/1996 to 2006/2007. Ugeskr Laeger 2007;169:4271-5.
15. Gilron I, Weaver DF. Blast injuries. Sang 1993;52:331-9.
16. Ritenour AE, Baskin TW. Primary blast injury: Update on diagnosis and treatment. Crit Care Med 2008;36:S311-7.
17. Guermazi A, Hayashi D, Smith SE, Palmer W, Katz JN. Imaging of blast injuries to the lower extremities sustained in the Boston marathon bombing. Arthritis Care Res (Hoboken) 2013;65:1893-8.