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Blast injury of the hand in a pediatric patient with open fracture: A case report

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Case Report

ABSTRACT

Blast injuries can cause severe, multi-tissue damage, including open fractures and extensive lacerations. Management of pediatric hand blast injuries is particularly challenging due to a high risk of contamination and infection. We report the case of a 10-year-old boy who sustained a left-hand blast injury caused by a firecracker. The patient presented with a contaminated lacerated wound, active bleeding, tissue avulsion, and retained foreign bodies, accompanied by crepitus and cyanosis of the index finger. Initial management included debridement and irrigation. Surgical intervention consisted thorough debridement, exploration of tendon and neurovascular structure, and K-wires fixation of the index finger. Despite appropriate initial management, the patient developed chronic necrotic tissue infection, necessitating ray amputation of the index finger to control the infection. Further evaluation suggested that primary vascular disruption, exacerbated by contamination and infection, contributed to progressive necrosis, particularly at the metacarpophalangeal level. To prevent further infection spread and salvage overall hand function, repeated debridement followed by amputation at the metacarpophalangeal joint and removal of fixation wires was performed. Structured rehabilitation was subsequently initiated. Pediatric hand blast injuries represent complex traumatic conditions with a high risk of tissue necrosis. Early diagnosis and aggressive surgical management are essential; however, compromised tissue viability and severe infections may necessitate amputation as a limb-salvage strategy. This case underscores the importance of comprehensive management and highlights the need for improved community-based prevention efforts.

INTRODUCTION

Blast injuries resulting from pyrotechnic devices represent a significant cause of severe hand trauma, particularly in the pediatric population.[1,2] Although global epidemiological data indicate a persistence burden of firework-related injuries despite safety regulations, the incidence remains disproportionately high in developing nations.[3] In Indonesia and across Southeast Asia, although comprehensive national registry data is lacking, hospital-based reports suggest an increasing trend in such injuries. A study from Surakarta reported that adolescents aged 11–20 years accounted for 31% of firecracker-induced hand fractures, with males comprising 78% of the individuals.[4] This issue presents a unique public health challenge, partly due to the cultural entrenchment of firecracker use during religious festivities, often involving unregulated or self-assembled explosives devices.[5]

The mechanism of injury is multifactorial, involving both thermal burns from the explosion and the kinetic energy generated by the blast wave.[6] When detonation occurs within a closed fist, the hand absorbs the full force of the blast, resulting in a zone of injury that extends far beyond the visible wound margins.[7] Consequently, these injuries often involve composite tissue loss affecting the skin, intrinsic muscles, neurovascular structures, and skeletal components,

frequently presenting as open fractures with severe contamination.[8,9] Management of these complex injuries in pediatric patients requires a careful balance between preserving limb function and growth potential and preventing life-threatening complications.[8] Although pediatric bone demonstrates significant remodeling capacity, immature soft tissues are particularly vulnerable to compartment syndrome and rapidly progressive necrotizing infections.[10] Accurate assessment of tissue viability during initial debridement is critical; underestimation of necrosis may result in repeated surgical intervention and prolonged morbidity.[11] This case report aims to illustrate the deceptive progression of tissue necrosis following blast injury and to critically evaluate the risks associated with primary wound closure.

CASE DESCRIPTION

A 10-year-old boy was brought to the Emergency Department approximately 30 minutes after sustaining a blast injury to his left hand caused by the premature explosion of a firecracker. He presented with severe pain, active bleeding, gross deformity of the index finger, and inability to move the affected hand. The patient denied loss of consciousness and reported no associated injuries to other body regions. There was no prior history of trauma to the affected hand. His medical history was unremarkable, with no known bleeding disorders, chronic illnesses, prior surgeries, regular medication use, or drug allergies. Family history was non-contributory, and developmental and psychosocial histories were appropriate for age.

On primary survey, airway, breathing, circulation, and neurological status were stable, with no life-threatening conditions identified. Vital signs were within normal limits: blood pressure 110/80 mmHg, pulse rate 100 beats per minute, respiratory rate 20 breaths per minute, and body temperature 36.5°C.

Local examination (Figure 1) revealed a severely contaminated lacerated wound with extensive soft tissue avulsion and retained explosive debris. The index finger demonstrated pallor and palpable crepitus, while the thumb and remaining digits appeared pale to cyanotic and were cold on palpation, suggesting vascular compromise. Radiographic evaluation confirmed a complete transverse displaced fracture of the middle phalanx of the index finger (Figure 2). Based on the mechanism of injury, degree of contamination, and extent of soft tissue damage, the injury was a primary blast injury (Zuckerman classification type I). Initial laboratory findings were unremarkable; however, inflammatory markers were monitored during follow-up.

Figure 1. Clinical presentation of the left hand blast injury in various positions: a) supination; b and c) pronation.

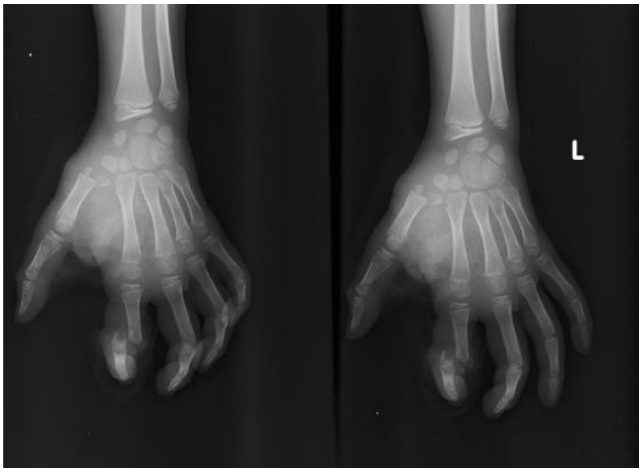

Figure 2. Radiohrapic imaging of the left hand

Initial management consisted of aggressive wound irrigation with three liters of normal saline, hemorrhage control, and administration of analgesia, tetanus prophylaxis, and empirical broad-spectrum intravenous cephalosporin antibiotics. The patient underwent emergency surgery under general anesthesia within four hours of presentation.

Intraoperatively, tissue viability was assessed using distal oxygen saturation monitoring and evaluation of capillary perfusion at the wound margins. The procedure involved extensive debridement, followed by exploration of the tendinous and neurovascular structures, and stabilization of the index finger using Kirschner wires (K-wires). This fixation method was selected to provide adequate skeletal stability while minimizing additional soft tissue trauma and implant bulk, particularly in the pediatric hand. Ruptured flexor tendons were repaired. Despite significant contamination, primary wound closure was performed using a loose suturing technique to facilitate drainage of residual contaminants and exudate while maintaining adequate soft tissue coverage. Postoperatively, the patient received intravenous cefazolin, oral ibuprofen for analgesia, and routine wound care with paraffin gauze dressings.

After three days of inpatient observation, the patient was discharged with oral medication and instructions for outpatient wound care. Follow-up included daily wound care and clinical evaluation every two days. Two weeks after the initial surgery, a second procedure was performed following clear demarcation of necrotic tissue (Figure 3). This intervention included repeat debridement, necrotomy, desloughing, hardware removal, and definitive disarticulation amputation of the index finger at the metacarpophalangeal (MCP) joint to control infection.

Figure 3. Necrosis of the left index finger at the metacarpophalangeal level

Postoperatively, the patient was hospitalized for an additional three days for monitoring and intravenous antibiotic therapy, followed by continued home-based wound care using topical gentamicin and advanced wound dressings. Subsequent follow-up demonstrated progressive wound healing, resolution of infection, and declining inflammatory markers. At one- and two-month evaluations, the surgical site was dry and well healed (Figure 4). Functional assessment revealed reduced grip strength but preserved range of motion in the remaining digits. The patient was subsequently enrolled in a structured rehabilitation program under the supervision of a physical medicine and rehabilitation specialist. No unexpected complications or adverse events

were observed. The chronological progression of the patient's condition and management is summarized in Figure 5.

Figure 4. Clinical condition of the left hand after one month (a) and two months (b) of recovery

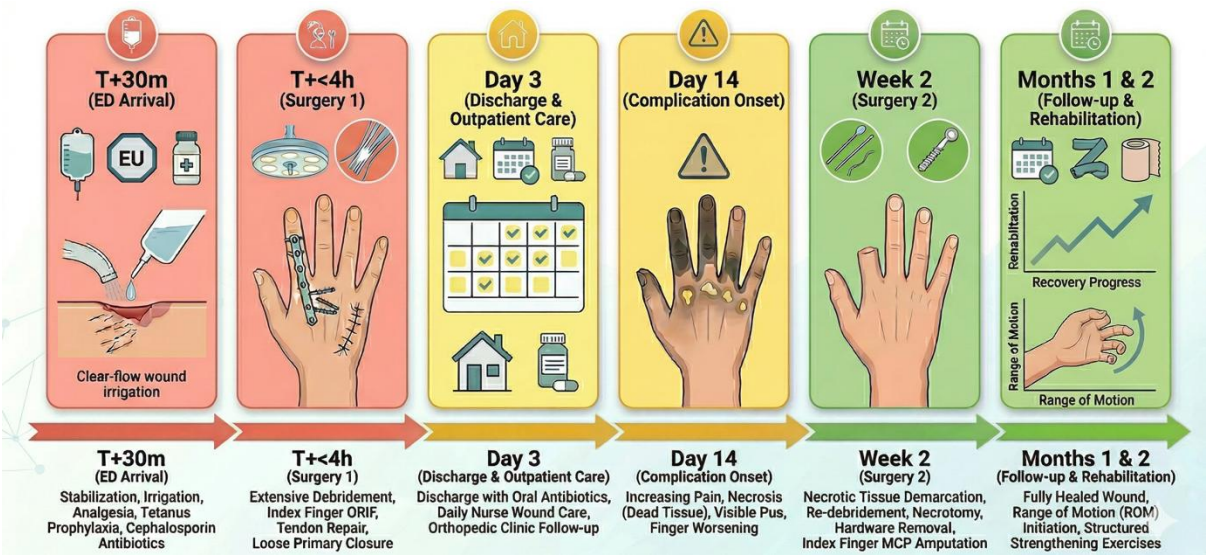

Figure 5. Timeline of patient management

DISCUSSION

Blast injuries from firecrackers generate high explosive power with irregular patterns of destruction and chemical contaminants.[5] In pediatric patients, thinner soft tissues and bones with a high proportion of growth plates reduce the capacity to dissipate blast energy, resulting in severe damage to muscles, tendons, and neurovascular structures, often manifesting as complex open fractures.[12,13] Furthermore, children have a relatively stronger ligaments compared to bone, making fractures more common than joint dislocations in blast trauma.[14]

Early surgical debridement remains a cornerstone in the management of open extremity injuries to reduce contamination and prevent infection. However, current evidence suggests that the timing of intervention should be individualized based on patient stability and injury severity rather than adhering to rigid time threshold.[15] In this case, emergency surgery was performed within four hours of presentation following initial stabilization, aiming to limit further tissue deterioration and facilitate prompt wound decontamination and structural repair. Empirical broad-spectrum antibiotic prophylaxis with cephalosporins (cefazolin injection intravenous) was initiated in the emergency department to target the polymicrobial flora commonly associated

with contaminated blast wounds.[16] Intraoperative assessment of tissue viability extended beyond conventional macroscopic indicators such as color and contractility. Distal oxygen saturation monitoring and evaluation of capillary perfusion were used to assess tissue perfusion around the injury zone.[17] This approach is particularly important in blast injuries, where the deceptive 'zone of injury' may obscures the true extent of devitalized tissue during the initial evaluation.[7]

The decision to perform primary wound closure in contaminated blast injuries remains a subject of clinical debate.[18] In this case, loose primary closure using non-tension sutures was performed to allow drainage of residual contamination and exudate while protecting repaired tendons and neurovascular structures.[19] Nevertheless, delayed primary closure is generally recommended in blast-related extremity injuries due to the high level of contamination and the dynamic evolution of tissue viability, permitting repeated debridement and reassessment prior to definitive closure.[20] K-wires were selected for fracture fixation to provide adequate stability while minimizing additional soft tissue trauma, particularly in the pediatric hand.[21] However, metallic implants may act as a nidus for bacterial biofilm formation, protecting pathogens from host immune responses and systemic antibiotics therapy.[22]

The progression of necrosis in this patient was likely multifactorial, involving primary blast-induced vascular injury compounded by secondary liquefactive necrosis from bacterial infection.[23] Amputation of the left index finger at the metacarpophalangeal (MCP) joint was undertaken once limb salvage was no longer feasible, as retention of devitalized tissue posed a significant risk of ongoing morbidity.[11] Although ray amputation is often advocate for improved cosmetic outcomes through closure the interdigital cleft,[24] it requires extensive dissection into the palm and may increase the risk of spreading infection into deep palmar spaces in the acute setting.[25] Therefore, MCP joint disarticulation was selected as a damage-control procedure to arrest infection, remove necrotic tissue, preserve palm architecture, and minimize surgical trauma, despite its association with reductions in pinch and grip strength by up to 33.6% and 43.3% respectively.[5,26]

Definitive surgical intervention was delayed for two weeks to allow clear demarcation tissue, thereby optimizing preservation of viable structures and functional outcomes.[25] Loss of the index finger in pediatric patients has significant long-term implications, as it plays critical role in pinch grip, power grip, and fine motor function.[27] Amputation may adversely affect hand function, motor development, and psychosocial adaptation.[11] Comprehensive rehabilitation is therefore essential to minimize long-term disability.[28] A structured rehabilitation program focusing on compensatory pinch mechanics and range-of-motion exercises for the remaining digits is crucial to restore function and prevent secondary complications such as joint contractures.[7]

This case highlights the challenges in accurately assessing tissue viability in the early phase of blast injuries, particularly in heavily contaminated wounds. Despite prompt surgical intervention, injury progression may occur due to the dynamic nature of the zone of injury and the risk of secondary infection. These findings underscore the importance of repeated clinical reassessment and timely escalation to definitive damage-control procedures when limb salvage is no longer achievable.

CONCLUSION

Pediatric hand blast injuries may lead to complex open fractures and severe infection despite early surgical intervention. Accurate assessment of tissue viability, meticulous debridement, and close postoperative monitoring are essential, as progressive infection and irreversible tissue damage may preclude limb salvage and necessitate amputation as a damage-control strategy. These findings underscore the importance of early recognition, vigilant follow-up, and strengthened preventive measures to reduce firecracker-related injuries in children.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest related to this case report. The authors confirm that no financial or personal relationships with other individuals or

organizations have inappropriately influenced the work reported in this manuscript. Written informed consent for publication was obtained from the patient's parents.

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DATA AVAILABILITY STATEMENT

The data supporting the findings of this case report are contained within the manuscript. Additional clinical details are not publicly available due to ethical and privacy considerations but may be provided by the corresponding author upon reasonable request.

SUPPLEMENTARY MATERIAL(S)

No supplementary materials were included in this case report.

AUTHORS CONTRIBUTIONS

The authors confirm their contributions to the manuscript as follows: study conception and design: A.N., A.A.Z., and T.N.Y.; clinical management and patient care: A.N.; case supervision and discussion: T.N.Y.; data collection: A.A.Z. and A.N.; draft manuscript preparation: A.A.Z. All authors reviewed and approved the final version of the manuscript and take responsibility for the integrity of the work.

DECLARATION OF USING AI IN THE WRITING PROCESS

The authors declare that artificial intelligence (AI)-assisted tools were used solely for language editing and grammatical refinement during the preparation of this manuscript. All clinical data, diagnostic assessments, therapeutic decisions, and scientific interpretations were entirely generated and verified by the authors. The use of AI did not influence the originality, clinical judgment, or scientific conclusions of this case report.

LIST OF ABBREVIATIONS

MCP: Metacarpophalangeal; NSTI: Necrotizing Soft Tissue Infection; BOAST: British Orthopaedic Association Standards for Trauma

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