ACS Case Reviews in Surgery
Vol. 2, No. 2

Management of an Undetonated Intracranial Explosive: A Multi-Disciplinary Approach Including the Bomb Squad

AUTHORS:
David P. Stonko MD, MS[a]; Richard D. Betzold, MD[b]; Seth A. Bellister, MD[b]; Dillon C. O'Neill, MD[c]; David E. O'Neill, MD[d]; Parker T. Evans[e]; Jillian G. Goles, MSPAS, PA-C[b,e;] Bradley M. Dennis, MD, FACS[b]

Drs. Stonko and Betzold contributed equally to this work

CORRESPONDENCE AUTHOR:
Dr. David Stonko
The Johns Hopkins Hospital
1800 Orleans St. - Tower 110
Baltimore, MD 21287
dstonko1@jhmi.edu

AUTHOR AFFILIATIONS:
a. The Johns Hopkins Hospital, Department of Surgery, Baltimore, Maryland 21287
b. Vanderbilt University Hospital, Department of Surgery, Division of Trauma and Surgical Critical Care, Nashville, TN 37212
c. The University of Utah, Department of Orthopedics, Salt Lake City, Utah 84108
d. UT Southwestern, The Department of Orthopedic Surgery, Dallas, Texas 75309
e. Vanderbilt University Hospital, Department of Surgery, Division of Trauma and Surgical Critical Care, Nashville, Tennessee 37212

Background	A uniquely injured 47-year-old male who presented with an undetonated intracranial aerial firework requiring operative removal, performed in the presence of the local bomb squad.
Summary	This patient suffered a penetrating traumatic brain injury from an aerial firework that was unintentionally loaded in an inverted position and launched while the device was positioned over his head. He was intubated at the scene due to combativeness and was hemodynamically stable on arrival in the emergency department. Subsequent physical examination and CT imaging revealed an open skull fracture with a retropulsed foreign body and right frontal temporal intraparenchymal hemorrhage with associated subarachnoid and subdural hemorrhage as well as bilateral hand wounds. The patient underwent emergent right frontal craniectomy, right frontal lobectomy, and removal of the foreign object. As the firework was undetonated, the local metropolitan bomb squad was assembled in the operating theater. At the suggestion of these experts, the surgeons refrained from using electrocautery until the projectile was removed. The patient convalesced from his uncomplicated operation but ultimately required a tracheostomy for ventilator management as well as additional orthopedic care. On postop day 31 he was discharged to a rehabilitation center. Upon follow-up he had returned to what his family reported to be his baseline mental status. He was ambulating, and performing his pre-injury activities of daily living.
Conclusion	Although the incidence of firework-related injuries has been reported, the complexities of an undetonated intracorporeal explosive or the complex operative management of this scenario has not. Our group successfully managed this case in a multi-disciplinary fashion that included the consultation of munitions experts.
Keywords	Munitions, firework related trauma

PRIOR MEETING PRESENTATION:
The 47th annual Western Trauma Association Meeting, Snowbird UT, March 2017.

DISCLOSURE:
The authors have no conflicts of interest to disclose.

To Cite: Stonko DP, Betzold RD, Bellister SA, et al. Management of an Undetonated Intracranial Explosive: A Multi-Disciplinary Approach Including the Bomb Squad. *ACS Case Reviews in Surgery*. 2018;2(2):42-45.

Case Description

A 47-year-old patient sustained a penetrating intracranial injury while attempting to launch an aerial firework. He reports unintentionally placing the shell into the device upside down (so the firework was pointing toward the bottom of the tube, instead of pointing out of the tube as would be appropriate), and holding the loaded firework and tube above his head during launch. Because the firework was loaded inverted the firework launched down, and was propelled through the bottom of the tube and toward the patient's head. This resulted in an open head injury and the family contacted emergency medical services (EMS).

EMS intubated the patient at the scene due to combativeness and he was transported to the regional level 1 trauma center. He was hemodynamically stable upon arrival (HR: 94, BP: 120/90, Oxygen saturation: 98 percent while intubated) and his GCS was 3T. Primary survey revealed an open head injury with skull fracture and bilateral hand wounds. Emergent computed tomography (CT) imaging revealed an open skull fracture in association with a retropulsed foreign body, a right frontal temporal intraparenchymal hemorrhage, and both subarachnoid and subdural hemorrhage (Figure 1), in addition to mandible fractures. Further imaging revealed a left scaphoid pole fracture. The family reported that the charge (i.e. component of firework that launches it into the sky) of the firework had been spent during the accident. However, it was unclear whether the shell ("effect" portion of the firework) was still active. Therefore, the device was assumed to be undetonated, and the local municipal bomb squad was consulted for munitions expertise.

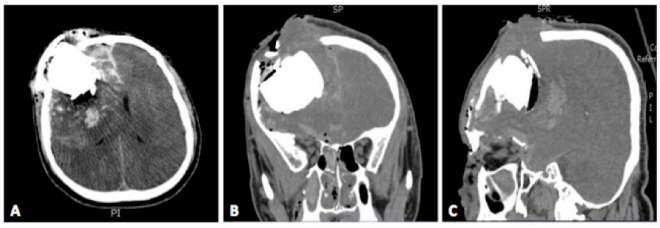

Figure 1. Preoperative CT images (**A:** axial, **B:** Coronal, **C:** Sagittal) of the retained intracranial explosive and associated open skull fracture, intraparenchymal and subarachnoid hemorrhage secondary to fireworks injury.

Based on clinical and radiologic findings, this patient underwent emergent right frontal craniectomy, right frontal lobectomy, and removal of a foreign object. The bomb squad was assembled in the operating theater and, at the suggestion of these experts, the surgeons refrained from using electrocautery until the foreign body was extricated and removed from the field. Once removed operatively, the explosive was safely transported by the bomb squad to a location outside of the hospital campus where it was permanently destroyed.

Postoperatively, the patient required tracheostomy for ventilator management and orthopedics was consulted for the bilateral hand wounds. The infectious disease team was following at this point because of the foreign body. Their final recommendations after culture data revealed 2+ yeast, isolated bacillus species, and moderate candida at the scalp incision was meropenem 2mg IV q8 hours, vancomycin, and fluconazole 400mg PO q24 hours, for which the patient ultimately received a PICC line. On postinjury day four, the patient underwent incision and drainage with orthopedics on his left upper extremity with placement of negative pressure wound therapy dressing. On postinjury day 10 he returned to the operating room with neurosurgery for cranialization of his frontal sinuses and with plastic surgery for repair of his mandibular fractures. On postinjury day 31, he was discharged to an inpatient rehabilitation center and follow up was organized with the trauma TBI clinic, orthopedics, and psychiatry. Upon follow-up, he had returned to his baseline mental status. At this time, he was ambulating and reported returning to his preinjury activities of daily living.

Discussion

Firework related injuries are common in the United States. A recent study estimates that 97,562 firework-related injuries were treated in U.S. emergency departments between 2000 and 2010 alone.[1] In 2015, fireworks accounted for almost 12,000 injuries, with 8,000 of those occurring between the peak injury dates of June 19 and July 19.[2] Eleven fatalities associated with firework use were reported during this time period, with nine (82 percent) being associated with reloadable aerial devices. This indicates there may be increased risk associated with these devices, as seen in this case. It has also been reported that firework shells cause a disproportionate level of permanent injury to the hands and eyes than other body organs,[3] injuries to the hands alone account for 36 percent of firework-related injuries.[4] Trauma due to fireworks has been reported and well documented in the literature for these injuries,[1,3–7] but the successful management of a retained, undetonated, intracorporeal or intracranial explosive device has not been described to our knowledge. Here, we discussed the case of a 47-year-old male uniquely injured by an undetonated intracranial aerial firework, which required operative removal and was performed in the presence of the local

bomb squad.

Modern fireworks are variable in design, and it remains impractical for a surgeon to maintain expertise in their technical elements. Despite this, as demonstrated in this report, the possibility remains that a surgeon may be called on to operatively remove potentially undetonated fireworks or similar munitions. Unfortunately, the stakes and time constraints of such as situation preclude a literature review before acting. Thus, *a priori* consideration of the technical and logistical constraints that this situation presents is required.

These authors first suggest that early consultation of local munitions experts such as a bomb squad may prove useful for minimizing the probability of further harm to the patient or caregivers due to iatrogenic ignition. Not surprisingly, the Department of Defense has extensive experience with the unexploded ordnance.[8] Our successful management of this injured civilian with retained firework was in accordance their practice guidelines for unexploded ordnance, as was the subsequent destruction. Fortunately our case involved a firework, and not a more dangerous device such as a grenade. However, it remains possible that in the future a civilian trauma team may encounter such a situation. In this event, the Department of Defense guidelines may be used to generalize our experience to more diverse munitions or scenarios, so we have provided a summary of their recommendations that may be applicable to a civilian trauma team. In their recommendations, they first suggest to initially obtain an understanding of the ordinance triggering mechanism. We posit that in the civilian setting this requires munitions experts, such as the bomb squad in our scenario, to accomplish this safely, because most civilian surgeons will have had minimal training or exposure to this scenario. Most modern trauma centers at large hospitals have on-site law enforcement. These law enforcement groups should have direct communication channels with the often larger and more equipped local or state law enforcement agencies and can therefore facilitate expedient arrival of local munitions experts. Therefore, immediately alerting the local campus police to the situation should provide a practical method for obtaining the expert munitions help that we suggest.

The military practice guidelines also recommend that all of the patient's personal items be screened or left outside of the medical treatment facility to avoid bringing additional munitions into the facility. Regarding imaging, they suggest that plain radiographs are safe, but that the patient "should not be reoriented to obtain the films as any movement can inadvertently complete the arming or triggering mechanism and cause an explosion." They further note that CT and ultrasound have not been explored in the literature. However, we did perform a CT scan (Figure 1) that proved to be safe. In addition to electrocautery, the guidelines also state "mechanical blood warmers, monitors, blood pressure gauges, infusers, or pumps should be minimized in order to reduce the risk of static electrical discharge" and suggest the use of mechanical instruments over electrical tools if they are needed (for example, a hand saw or drill is preferred over electric saw or drill). They further advise against the use of combustible agents in the vicinity of the patient. Though not possible with our patient, they suggest that if the ordinance is in an extremity that anesthesia may be limited to nerve blocks in order to limit combustible sources within proximity. Regarding surgical strategy, they suggest that when presented with retained combustible element that it should be removed by the most expedient means possible, and that this often lends itself to en bloc resection of the surrounding tissue or, if the device is located within the extremity, then amputation may be most expedient. Twisting, pushing, or pulling of the device should be avoided at all costs to avoid triggering the device or creating friction. Furthermore, unnecessary touching of the device and all vibration should be minimized by stabilizing the extremity or body segment. Definitive treatment and limb saving procedures may need to be delayed in order to facilitate the safe removal of the ordnance, which they suggest should be handed off to a munitions expert to be destroyed, as we did in our case. Lastly, these guidelines note that no known chemical or biological munitions impalements have been documented, but that if this were to happen, then the guidelines recommend considering that while these devices tend to have a smaller explosive force, they often have the capacity to affect medical personnel. Otherwise, there is no data available to make evidence based suggestions for this scenario. We suggest that knowledge of these recommendations is extremely important for both the surgeons and munitions experts that may be assisting in the civilian trauma theater.

We further suggest that the surgical team assume that all suspected munitions are undetonated, and therefore avoid all diagnostic or treatment modalities that pose risk of detonation. These include but may not be limited to electrocautery or energy devices. Unnecessary risk to hospital personnel may be mitigated by munitions expert support, and by limiting patient-provider interaction to those providers absolutely necessary and even then by maintaining the greatest feasible distance from the explosive. This may mean that at times the surgeon is the only person directly

involved in the patient's care and may need to perform additional roles typically reserved for other hospital staff (for example, scrub techs, bedside nurses, and patient care technicians). The munitions experts also provide the safest mechanism for removal of dangerous foreign objects from the hospital campus and are best tasked with the subsequent destruction.

Conclusions

Despite the prevalence of firework related injuries, the complexities of an undetonated retained intraparenchymal explosive had not been previously reported. Our group successfully managed this in a multidisciplinary fashion with the aid of munitions experts.

Lessons Learned

Intracorporeal munitions should be assumed to be undetonated upon presentation. If explosives are suspected, consultation by a bomb squad or equivalent munitions expert for guidance and destruction is indicated, in accordance with Department of Defense guidelines. We also suggest that electrocautery or energy devices may be contraindicated until removal in this scenario. Minimizing exposure and therefore risk to hospital personnel by limiting patient interaction to the minimum number of providers should be considered. Review of this complex case may be beneficial to trauma surgeons, munitions experts, and law enforcement personnel.

References

1. Moore JX, McGwin G, Griffin RL. The epidemiology of firework-related injuries in the United States: 2000-2010. *Injury*. 2014 Nov;45(11):1704–1709.
2. Tu YL. 2015 Fireworks Annual Report . Consumer Product Safety Commission. https://www.cpsc.gov/s3fs-public/Fireworks_Report_2015FINALCLEARED_0.pdf?2M-9KQg40aQyjI_0M.o0KLZOZFGEvGnA7. Accessed Mar 13, 2018.
3. Sandvall BK, Jacobson L, Miller EA, et al. Fireworks type, injury pattern, and permanent impairment following severe fireworks-related injuries. *Am J Emerg Med*. 2017 Oct;35(10):1469–1473.
4. Saucedo JM, Vedder NB. Firework-related injuries of the hand. *J Hand Surg Am*. 2015 Feb;40(2):383–387; quiz 387.
5. Chang IT, Prendes MA, Tarbet KJ, Amadi AJ, Chang S-H, Shaftel SS. Ocular injuries from fireworks: the 11-year experience of a US level I trauma center. *Eye (Lond)*. 2016 Oct;30(10):1324–1330.
6. Yasmeh S, Trasolini NA, Li W-Y, Yang H, Ghiassi A. Firework-related hand injuries: A novel classification system. *Am J Emerg Med*. 2018 May;36(5):897–899.
7. Kuhn F, Morris R, Witherspoon CD, Mann L, Mester V, Módis L, et al. Serious fireworks-related eye injuries. *Ophthalmic Epidemiol*. 2000 Jun;7(2):139–148.
8. John Oh L, LTC Jason Seery U, LCDR Daniel Grabo U, Col, et al. Unexploded Ordnance (UXO) Management. Joint Trauma Systems Clinical Practice Guidelines. http://jts.amedd.army.mil/assets/docs/cpgs/JTS_Clinical_Practice_Guidelines_(CPGs)/Unexploded_Ordnance_UXO_Management_14_Mar_2017_ID41.pdf. Accessed Mar 25, 2018.