**Title and Subtitle**
An Impaled Potential Unexploded Device in the Civilian Training Trauma Setting: A Case Report and Review of the Literature

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Abstract:

Background: The management of patients with impaled unexploded devices is rare in the civilian setting. However, as the lines of the traditional battlefield are blurred by modern warfare and terrorist activity, emergency providers should be familiar with facility protocols, plans, and contact information of their local resources for unexploded devices.

Case Report: A 44-year-old male sustained a close-proximity blast injury to his lower extremities while manipulating a mortar-type firework. He presented to the regional trauma center with an open, comminuted distal femur fracture and radiographic evidence of a potential explosive device in his thigh. His management was coordinated with the local Explosive Ordnance Disposal (EOD) and the Fire Department.

Why should an emergency physician be aware of this? Explosive devices pose a grave threat when encountered. Familiarization with protocols to manage these patients can mitigate disaster. Emergency providers should expect and be prepared to coordinate care for these patients.

Key Words: Unexploded Ordinance, UKO, Explosive, Firework, Foreign Body, Pyrotechnic, Firework

Introduction

Recent terrorist activity has blurred the lines of the battlefield. Mass casualties from unfortunate events in Manchester, England; Paris, France; and Boston, Massachusetts have taught us that even physicians in urban setting should be familiar with the general principles regarding the triage, diagnosis, and management of explosive device injuries. With distance from the explosion epicenter being directly related to lethality, such mass-casualty scenarios produce large variation in mortality and morbidity. All of these patients, including expectant casualties, remain the emergency provider’s responsibility.

Additionally, emergency physicians need to know how to manage a patient with an impaled unexploded device. Improper management can have catastrophic consequences for the patient, the hospital, and the medical team. The presence of such a device will undeniably cause a heightened state of anxiety, and preparation for such an occurrence can minimize errors. (1) We present a case of a patient with an impaled potentially unexploded device in a patient’s leg and a review of precautions to take in similar scenarios.

Case Report

A 44-year-old Caucasian male presented to the emergency department of a U.S. Level III Trauma Center as a transfer via ground ambulance after he sustained a close-proximity blast injury to his lower extremities while manipulating a mortar-type firework. The patient was reloading the device, after a presumed dud or misfire, when an explosion caused injury to his right leg. He believed the mortar firework he was loading had propelled into his leg during the explosion. He was evaluated by EMS in the field where his limb was noted to be grossly unstable with a large anterior soft tissue wound. A pressure dressing and tourniquet were applied and he was transported to a local, Level IV Trauma Center. At this facility, the tourniquet was deflated and he was treated with cefazolin, tetanus toxoid, a pressure dressing and a leg splint. His tourniquet was reapplied to minimize blood loss during his transfer.

The patient arrived in emergency department of our Level I Trauma Center at 244 minutes from initial injury. The patient was examined in accordance with ATLS principles. Primary survey was unremarkable. He was noted to have a blood pressure of 119/66mmHg, heart rate of 82 beats per minute, respiratory rate of 16 breaths per minute, oxygen saturation of 99% on room air, and an oral temperature of 97.8°F. On secondary survey, the patient had significant pain localized to his right thigh. The tourniquet and pressure dressing were removed and exam revealed a large grossly contaminated, hemostatic wound on the right anterior thigh (Figure 1). Total tourniquet time was 168 minutes with a 77-minute tourniquet-free interval while at the outside facility. He had palpable dorsalis pedis and posterior tibial pulses with a normal motor and sensory exam. The remainder of his physical examination was unremarkable. The patient denied comorbid medical conditions. However, his history was significant for a high-velocity gunshot wound sustained twelve years prior to his right leg and left thigh with associated vascular injury. These injuries required reconstruction of the superficial femoral artery, four-compartment fasciotomies, and multiple subsequent
Surgery. The patient underwent several rounds of debridement and irrigation during
the initial discussion with the EOD, it was determined that an unexploded
ordinance or simple ballistic device requires an understanding of clinical and radiological
features of projectiles with explosive potential. (6) It should always be assumed that a
malfunction has occurred causing the ordinance to malfunction. Any bypass of these
failed mechanisms through patient handling or surgical removal could potentially
trigger a detonation.

Discussion

Most literature on unexploded devices is derived from unexploded ordinances
(UXO) in the military setting, where such devices are most commonly seen. (1, 2) A UXO
is defined as military munitions that have been primed, fused, or armed and have been
fired, dropped, launched, or projected to create hazard for military operations and
remain unexploded either by malfunction, design or any other cause. (4) Other
unexploded devices can be improvised explosive devices (IEDs) that range from
"homemade" explosives to sophisticated weapon systems, including roadable
explosives, explosive formed projectile devices and suicide bombs. (5)

In the United States military medical literature, there have only been 39
documented cases of impaled UXO since the Korean War. (3) In a review article
published by Len et al. in 1999 multiple cases were reviewed from the Somalia conflict.
Of note, in 36 patients with reported impaled UXO, all underwent successful removal
without detonation. These patients were treated and transported with techniques to
avoid detonation of the devices. (3)

Recommendations from the Joint Trauma System Clinical Practice Guidelines for
the management of unexploded ordinance are set in place for both impaled and loose
devices. "Impaled" devices are any device that penetrates the body, whereas
"loose" is defined as in a jacket or external clothing. (2) All emergency rooms should
have an execution plan and set procedures in place for patients with loose or impaled
removal of these fuses, such as the one in our patient, requires thorough irrigation to
drown the fuse and main charge with the avoidance of electrocautery during removal.
Fuses encountered in military-grade munition are typically more complex. In some
devices, such as many types of rocket propelled grenades (RPGs), a threshold number of revolutions
is required for activation of the fuse. When such devices are used
at close-range, contact with a target may occur before the threshold has been reached.

Further manipulation (e.g. rolling) of such patients or the device after removal can
potentially activate the fuse after arrival at a medical facility. (3) In other devices,
usually mortar or rifle grenades, a mechanical pressure device employs a nail in the
cone or nose that is pushed down upon impact. (6) Pressure on the nose of these devices
could trigger detonation.

Another common type of detonating trigger is piezoelectric crystals which are
most commonly seen in handheld anti-tank grenades. Upon impact, these crystals
create an electric charge causing detonation. These crystals can also be triggered by the
use of electrical current, heat, reorienting the patient, or even direct sunlight. Finally,

Table 1: Examples of mechanisms that could cause detonation of an explosive device

- Moving the patient
  - Moving the gun with the patient
  - O Log rolling for spinal assessment
  - O Applying pressure to the target
  - O To access for tenderness or boney
  - O Stability
  - O Static electricity
  - O Electrocautery
  - O Heat
  - O Sunlight
  - O Radiofrequency
  - O Radio communication
  - O Cellphone use

In addition to training, plans can aid significantly in the care,
since the advent of improvised explosive devices (IEDs) and the relative ubiquity of

225 cellular telephones, many modern fuses have been designed for remote activation.

224 Since these can be detonated with radiofrequency, cellular telephones and other

223 radiofrequency communication devices should be removed from the area until the

222 device is properly disposed.[2]

221 In the emergency department, clinical and radiological studies provide

220 information that helps minimize patient and provider risk.[5] The radiologic evaluation

219 of a patient with a potential explosive device can be complicated. Plain radiographs are

218 considered safe in the evaluation of a UXO in the military setting, although the patient

217 should not be repositioned to obtain images.[3] It is unknown if “portable” x-ray which

216 communicates via wireless means is safe. The safety of ultrasound, CT, fluoroscopy, and

215 angiography have not been studied. A single study by Schlager et al. evaluated the

214 safety of imaging exploding bullets with ultrasound and found the method to be safe,

213 although this has not been evaluated with other ordinances.[10] It is recommended to

212 avoid advanced imaging modalities until further studies confirm their safety. If required,

211 follow the principle of proximal and distal control of vessels, safe removal of the device,

210 and temporary bony stabilization prior to advanced imaging.[2] MRI is contraindicated

209 as many UXOs are made with ferrous metals.[3]

208 It is recommended that if transporting a patient, care be taken to avoid a static

207 discharge by having both the care giver and the vehicle grounded electrically before

206 touching or transporting the patient. This can be accomplished by touching the ground

205 and the vehicle at the same time. This is especially important in helicopter transport as

204 the rotors can produce a static discharge.[7] Ideally, any transportation of the patient

203 would be done by EOD or a bomb squad.

202 After the patient has been safely transported to the operating room, several

201 basic tenants for removal of UXOs must be considered in addition to the usual principles

200 for the removal of impaled objects. An EOD team should be held on standby to identify

199 and dispose of the ordinance as soon as it has been removed from the patient.

198 Members of the surgical team should be fitted with body armor, ballistic eyewear, and

197 helmets until safe removal. Acquisition of such protective equipment should be

196 coordinated with EOD, law enforcement, or local bomb squad. The operating room

195 should be cleared of all non-essential personnel; however, sufficient assistance should be

194 employed intraoperatively to assist in visualization and permit the expeditious removal of

193 the device.[9] Use of electrocautery should be delayed until the device has been

192 completely removed. Burning fuses, such as those seen in most pyrotechnics, should be

191 drown with large volumes of irrigation fluid at low pressure. Removed devices should

190 be set gently in a soft or non-metal receptacle and immediately removed from the

189 operating theatre while avoiding perturbation of the UXO.

188 As a summary the situational unexploded ordinance practices outlined in the

187 Joint Trauma System Clinical Practice Guidelines adapted to the civilian setting include:

186 • Create a triage/search/blast contaminant area outside of the medical facility.

185 • When a potential unexploded device is found, immediately evacuate all non-

184 essential personnel from the immediate area and move to a safe distance or

183 protected area.

182

179 • Notify Explosive Ordnance Disposal team and local authorities.

178 • Move patient to a location away from the hospital and people for evaluation and

177 treatment. Always use appropriate personal protective equipment.

176 • Use the minimum number of personnel involved in patient treatment. Do not

175 use any electrical equipment that may detonate UXOs (e.g., electrocautery) and

174 decrease the presence of any alcohol-based solutions or combustible agents (e.g.

173 alcohol-based solutions, oxygen, combustible volatile anesthetic agent.[2]

172 These guidelines can help develop a basic plan or protocol for a UXO or IED.

171 In the emergency department, patients with explosive foreign bodies pose a

170 significant threat to the hospital, staff, and other patients. It falls onto the emergency

169 provider to manage the care and stabilization of these patients. Coordination with the

168 appropriate surgical, radiology, fire, police, hospital administration, and EOD should be

167 accomplished in the emergency department. Sometimes, retained objects can be

166 discovered later in the care course. Maintain a high level of suspicion in patients with

165 large penetrating trauma injury for possible explosive devices, and always handle these

164 patients with caution. Emergency providers should be familiar with their facilities plan

163 and procedures for potential explosive ordinances. If not present, consider

162 implementing a protocol and have contact information available for local resources.

161 Why Should an Emergency Physician Be Aware of This?

160 Although rare, unexploded devices can present in the civilian emergency

159 department. Emergency physicians should be familiar with types of devices and

158 triggering mechanisms as well as the correct handling of patients that could potentially

157 have an unexploded ordinance. Prior planning and protocols for explosive devices can

156 minimize mistakes and further casualties. While the patient described in this case was

155 found to have only part of the firework without a detonator in his thigh, this example

154 illustrates that these situations can occur in the civilian setting and emergency providers

153 should be familiar with the care and management of these patients.

152 References

151 1 Howell CM, Sonntagreif JL, Simonet LB. Unexploded Ordnance in an Expectant


149 2 Murray A. Unexploded ordinance (UXO). JT Trauma Syst Clin Pract Guidel


146 50-year military experience and current recommendations. Mil Med

145 2 1999;164:166-3.


143 5 Ramasamy A, Hill AM, Clasper JC. Improvised Explosive Devices: Pathophysiology,

142 Injury Profiles and Current Medical Management. J Fr Army Med Corps 2009;265-

141 72.

139 6 Young CR, Groshowski MF. The radiographic analysis of a wounded patient

138 questioned of having retained unexploded ordinance. Emerg Radiol 2016;23:521-
Weapons Effects and War Wounds.


Dill T. Contraindications to magnetic resonance imaging. Heart 2008;94:943-8.

Figure Legends

Figure 1: Photograph of injured extremity

Figure 2: X-ray of right femur with a potential imbedded firework

Figure 3: Management of Potential UXO