



Terrorist Bombings: Foreign Bodies from the Boston Marathon Bombing

John Brunner, MD,^{*,†} Ajay K. Singh, MD,[‡] Tatiana Rocha, MD,[†]
Joaquim Havens, MD,[§] Eric Goralnick, MD, MS,^{||} and
Aaron Sodickson, MD, PhD[†]

On April 15, 2013, 2 improvised explosive devices detonated at the 117th Boston Marathon, killing 3 people and injuring 264 others. In this article, the foreign bodies and injuries that presented at 2 of the responding level 1 trauma hospitals in Boston—Brigham and Women's Hospital and Massachusetts General Hospital—are reviewed with a broader discussion of blast injuries and imaging strategies.

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Introduction

At 2:49 PM on April 15, 2013, 2 improvised explosive devices (IEDs) constructed of pressure cookers laden with finishing nails, ball bearings, and screws exploded near the finish line of the 117th Boston Marathon. In this mass casualty incident, 3 people died at the scene and another 264 were injured.¹ Brigham and Women's Hospital (BWH) and Massachusetts General Hospital (MGH) of the Partners Healthcare System, both level 1 trauma centers, received 79 survivors in the immediate aftermath. This review details the types of blast injuries and the foreign bodies seen in the survivors of bombings with the goal of familiarizing radiologists and other responding clinicians with blast-related injuries and basic imaging strategies.

Types of Explosions

With a conventional explosion, a blast wave is created and spreads out from a point source, causing damage. The damage decreases exponentially with distance from the point source. The blast wave consists of 2 parts: an initial shock wave of high pressure and a subsequent blast wind. Enhanced-blast explosives

are created by using an initial blast to distribute and detonate other explosive charges. The use of such devices may result in greater damage because of prolonged duration, more extensive area of distribution, and higher energy generated by the device.^{2,3}

Types of Blast Injuries

The following are the 4 types of blast injuries that have been described: primary, secondary, tertiary, and quaternary (Table).^{2,3} This classification is based on the mechanism of injury, not the severity of injury. As an example, bowel perforation induced by the blast wave would be a primary injury, whereas a bowel injury caused by shrapnel would be a secondary injury. The severity of blast injuries is a function of the energy of the explosive device, the use of shrapnel and other morbidity-enhancing agents (ie, toxins), proximity to the device, and the placement of device, open vs closed space.^{3,4}

Primary Blast Injuries

Primary blast injuries are caused by barotrauma resulting from the initial pressure wave. The most common types of injuries involve air-filled organs and air-fluid interfaces because of dynamic pressure changes at tissue-density interfaces. The most common primary blast injuries are tympanic membrane (TM) rupture, lung injury, air embolization, and rupture of hollow viscera.

The TM is the most frequently injured structure, and injury to the TM occurs at the lowest pressure. If there is no rupture of the TM, primary effects of blasts on other air-containing organs are unlikely.⁵

*Department of Radiology, University of Southern California, Los Angeles, CA.

†Department of Radiology, Brigham and Woman's Hospital, Boston, MA.

‡Department of Radiology, Massachusetts General Hospital, Boston, MA.

§Department of Surgery, Brigham and Woman's Hospital, Boston, MA.

||Department of Emergency Medicine, Brigham and Woman's Hospital, Boston, MA.

Address reprint requests to John Brunner, MD, 348 South San Pedro, Apt 301, Los Angeles, CA 90012. E-mail: jbrunner@med.usc.edu, jackfbrunner@gmail.com

Table Blast Injuries

Type of Blast Injury	Mechanism	Injuries
Primary	Blast wave	Rupture of tympanic membrane Rupture of hollow viscera Lung injury or air embolism
Secondary	Projectiles striking the victim	Penetrating ballistic trauma Blunt ballistic trauma
Tertiary	Wind displacing victim's body or structure collapse	Penetrating trauma Blunt trauma
Quaternary	Secondary to fire, hot gases, and carbon monoxide	Burns or asphyxia Exposure to toxic agents

The lungs are the second most affected organs. Pulmonary injuries are life threatening and occur because of changes in the atmospheric pressure across the alveolar-capillary interface. Pulmonary contusions are the main manifestation. They occur on the side of approach of the blast wave when the victim is in an open space, but they tend to be bilateral and diffuse when indoors. Other presentations include hemorrhage, contusion, pneumothorax, hemothorax, pneumomediastinum, and subcutaneous emphysema. Systemic acute gas embolism can occur from pulmonary disruption.²

The colon is another visceral organ commonly injured by the blast wave. Rupture can occur immediately after the blast or secondary to mesenteric ischemia or infarct. Tension pneumoperitoneum and mesenteric, retroperitoneal, and scrotal hematomas may occur.²

In the case of the Boston Marathon bombing, the relatively small devices, proximity to the ground, and outdoor location resulted in immediate dissipation of the pressure wave, limiting primary injuries to TM rupture to victims in the immediate vicinity of the blast.^{6,7}

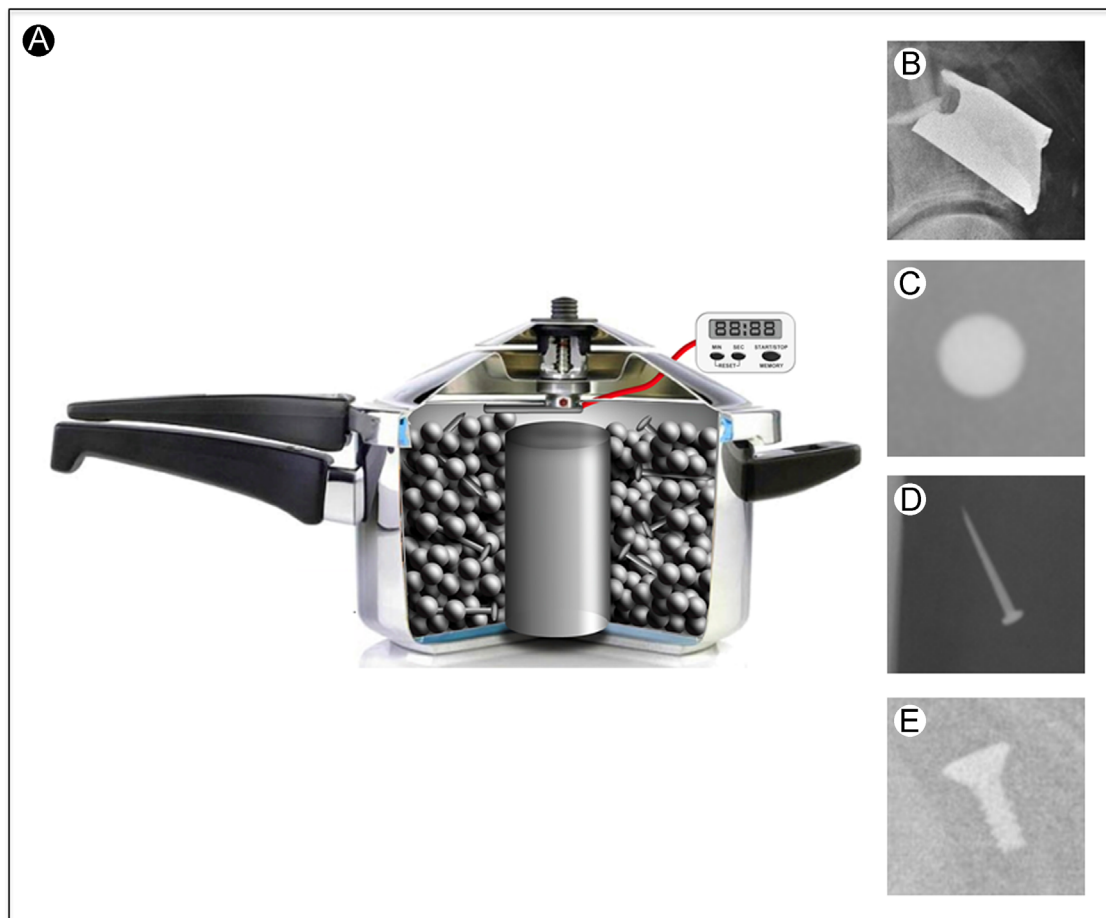


Figure 1 (A) Illustration of the improvised explosive device (IED) used in the Boston Marathon bombings, a pressure cooker filled with ball bearings and finishing nails. The foreign bodies encountered in radiographic imaging are derived from the devices components: (B) shrapnel derived from the pressure cooker, (C) ball bearing, (D) finishing nail, and (E) screw used in the construction of the device.

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