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Radiology's Role and Common Injuries in Mass Casualty Blast Incidents

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A B S T R A C T

The central role of radiology in the decision-making process for managing blast injury victims ensures a large percent of mass casualty patients will require radiology services during their initial assessment. The potential for movement of significant number of seriously injured patients through radiology requires familiarity with the mechanisms of blast injury, potential red flags for patients who should proceed to definitive care rather than additional studies, and early signs of deterioration to watch for while in the radiology department.

Introduction

Blast injury victims access our health-care system as a result of a variety of individual or mass casualty events. Although blast injuries are increasingly generated by terrorist attacks, they can also originate from accidental sources such as industrial accidents, natural gas explosions, and mining disasters. For the year 2016, The United States Bomb Data Center reported 15,943 explosives-related incidents and 699 explosions of which 439 were bombings (United States Bomb Data Center [USBDC] Explosives Incident Report [EIR], 2016). The diverse mechanisms of blast trauma mandate radiographic imaging as a fundamental component of the assessment and management decisions for the care of many blast victims. After the terrorist train bombing in Madrid in 2004 which killed 191 people, over 2,000 patients presented for evaluation to hospitals in the region. A small sample of those patients included 36 who were transported to the University Hospital La Paz trauma center and required 112 radiology studies including 64 plain radiographs, nine ultrasound studies, and 39 computerized axial tomography scans (CTs) during the first 3 hours of the event (Marti et al., 2006). After the bombing of the Murrah Federal Building in Oklahoma City in 1995, 265 patients were seen in the emergency department (ED). Radiology was the most frequently used service including plain radiographic studies for 45% of the patients and CT scans for 7.1% of cases (Hogan et al, 1999). One hundred twenty-seven of the 281 victims of the Boston Marathon bombing in 2013 were seen at one of 6 trauma centers. Their initial evaluation included 99 plain radiographs, 23 focused assessment with sonography in trauma examinations, and 32 CT scans (Gates et al., 2014).

Because many blast victims can be expected to require radiographic evaluation as part of their early assessment, it is important to consider the clinical presentations and potential pathologic processes that might impact patients while in the radiology department (RD). Using a chief complaint approach, the authors will review the potential pathology to be anticipated and addressed while monitoring blast injury victims during their initial evaluation.

Background: mechanisms of blast injuries

The Table 1 lists blast injury mechanisms consisting of a variety of well-described pathologic processes that can injure and kill (Dick et al., 2018; Marti et al., 2006; Singh et al., 2016a; b). Primary blast injury results from a variety of pathologic processes that occur when a shock wave strikes tissue. A rapid sequence of compression followed by expansion of gas-filled tissue has the potential to cause damage to structures including ears, sinuses, lungs, and bowel. The shock wave accelerates at different rates through tissues of different densities resulting in tissue shearing. This process is particularly devastating to the intricate structures of the lung (Mackenzie and Tunnicliffe, 2011; Ritenour and Baskin, 2008). Secondary blast injuries are the most frequent mechanism of trauma resulting from tissue penetration by blast propelled foreign bodies. In addition to shrapnel placed in the device, foreign bodies are created from the

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Table 1
Mechanisms of blast injury

Category	Characteristics	Body part affected	Types of injury
Primary	Unique to high-order explosives* and results from the impact of the over-pressurization wave with body surfaces	Gas-filled structures are most susceptible, including lungs, gastro-intestinal tract, and middle ear	Blast lung (pulmonary barotrauma), tympanic membrane and middle-ear damage, abdominal hemorrhage and perforation, globe (eye) rupture, and concussion (traumatic brain injury [TBI] without physical signs of head injury)
Secondary	Results from flying debris and bomb fragments	Any body part may be affected	Penetrating ballistic (fragmentation) or blunt injuries. Eye penetration (can be occult)
Tertiary	Results from individuals being thrown by the blast wind	Any body part may be affected	Fracture and traumatic amputation; closed and open brain injury
Quaternary	All explosion-related injuries, illness, or diseases not due to primary, secondary, or tertiary mechanisms, including exacerbation or complications of existing conditions.	Any body part may be affected	Burns (flash, partial, and full thickness); crush injuries; closed and open brain injury; asthma, chronic obstructive pulmonary disease, or other breathing problems from dust, smoke, or toxic fumes; angina; hyperglycemia; hypertension

* High-order explosives (HEs) produce a defining supersonic over-pressurization shock wave. Examples of HE include TNT, C-4, Semtex, nitroglycerin, dynamite, and ammonium nitrate fuel oil.
Centers for Disease Control and Prevention (n.d). Explosions and blast injuries. Retrieved 3-3-18 from https://www.cdc.gov/masstrauma/preparedness/primer.pdf

housing of the bomb and surrounding debris including body parts from suicide bombers and other victims. Tertiary blast injuries consist of blunt and penetrating trauma resulting from victims being thrown by the blast wave. Quaternary injuries are generally considered to be all other pathology resulting from the blast including burns, toxic gas, radiation, injury from falling debris, and exacerbation of preexisting conditions from dust and debris in the blast environment.

Clinical Presentations to Consider for Monitoring Blast Victims

Airway

Although victims of blast injuries can suffer immediate airway compromise, some may deteriorate later in their clinical course. Patients with facial injuries may lose airway patency in a variety of ways including hemorrhage, edema, foreign bodies, or movement of unstable fracture segments. In a similar manner, patients with penetrating neck injuries can lose their airway from foreign bodies, an expanding hematoma pressing on the trachea, laryngeal fractures, or massive subcutaneous emphysema from penetration of airway structures (Graham, 2012). Burns involving the airway can lead to progressive edema over time with potential airway compromise. Clinical signs such as singed nasal hairs and carbonaceous sputum suggest airway involvement in a burn patient. Massive hemoptysis from blunt or penetrating trauma to the chest, face, or neck can lead to sudden deterioration of the airway in patients who are initially stable. Finally, deterioration of mental status can be a stand-alone problem or a contributing factor to the other listed pathology resulting in loss of airway integrity. Early identification of impending airway compromise can facilitate early intervention and movement to a setting better equipped to provide emergency airway control. This is best accomplished by assessment on arrival at each location of care with ongoing monitoring for changes in patient mental status, ability to speak, respiratory rate, oxygen saturation, or the development of stridorous breathing.

Breathing

Breathing and airway assessments are closely linked because development of respiratory difficulty can be primarily an airway problem, a breathing problem, or a combination of both. The lungs are frequently injured in the victims of blast injuries through a variety of blunt and penetrating mechanisms. Primary blast lung occurs from the impact of pressure waves producing barotrauma involving airway disruption, alveolar rupture, and capillary bleeding (Adler and Rosenberger, 1988; Wightman and Gladish, 2001). This injury appears as unilateral or bilateral perihilar consolidation on chest radiographs or CT scan (Dick et al., 2018; Singh et al., 2012; Oikonomou et al, 2012). Although blast lung can lead to immediate life-threatening changes, victims may develop respiratory failure later in the course of their evaluation and treatment. Even patients who are intubated in the ED, before being sent to radiology, should be monitored closely for the development of a pneumothorax or arterial air emboli exacerbated by positive-pressure ventilation of the damaged lungs. In a similar manner, fluid resuscitation should be closely monitored to provide a sufficient volume for cardiovascular support while observing for signs of respiratory compromise due to capillary leak. In addition to the primary blast effect, shrapnel from the secondary blast effect as well as tertiary and quaternary blast effects can produce breathing problems due to pneumothorax, hemothorax, chest wall damage (Singh et al., 2016a; b), or fat emboli from fractures(Wightman and Gladish, 2001). Even blast victims without obvious chest injuries can potentially develop delayed breathing problems from environmental hazards at a blast site including smoke inhalation, dust triggering exacerbation of underlying lung disease, or toxins incorporated in the explosive device.

Circulation

Primary blast injuries are less commonly seen in lower intensity blasts, particularly those occurring in open spaces (Singh et al., 2014). However, in higher intensity blasts or those occurring in closed spaces, primary blast injury occurs more frequently resulting in lung injuries. Arterial air emboli from injured lung can impact a number of organs including the heart resulting in myocardial ischemia with circulatory compromise (Boutillier et al, 2016; Ritenour and Baskin, 2008; Singleton et al, 2013). Primary blast effects on the bowel occur less frequently but can lead to hemorrhage, perforation, and circulatory compromise (Dick et al., 2018; Singh et al, 2016a; b). Secondary blast injuries, which usually cause the majority of pathology, generate many opportunities to