

Blast Injury

Impact on Brain and Internal Organs



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KEYWORDS

• Blast injury • Polytrauma • Terrorism • Traumatic brain injury

KEY POINTS

- Injuries caused by blast effects may be incurred by both soldiers during wartime and civilians involved in terrorist incidents or industrial accidents.
- The injuries caused by blast are usually divided into primary (blast overpressure), secondary (fragmentation), tertiary (blunt trauma), and quaternary (burns, toxic exposures) effects.
- The most commonly injured systems are the lungs, brain, and extremities.
- Brain damage may be subtle but a source of long-term impairment.

INTRODUCTION

The use of explosives to kill and injure soldiers by blast effects probably goes back a thousand years, to the introduction of gunpowder to warfare. During the recent military conflicts in Iraq and Afghanistan, a higher proportion of casualties were caused by blast injuries compared with previous conflicts, because of the widespread adoption of improvised explosive devices (IEDs) by enemy forces.^{1,2} Coupled with a decreased case fatality rate,³ this means that a larger number of survivors of blast injuries have been treated in military and Veteran's Administration medical systems, which has brought increasing appreciation of the long-term effects of blast injury on the brain, even in less severely injured casualties.

Outside wartime, injuries caused by blast remain a threat to civilians as well. IEDs are a favorite weapon of terrorists, from nineteenth century bomb-throwing anarchists to the perpetrators of the recent Boston Marathon bombings. Major terrorist incidents

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of the twentieth and twenty-first centuries have relied on IEDs to kill and terrorize, be it a hijacked airplane or a gunpowder-laden pressure-cooker. In addition, industrial accidents such as the West Texas fertilizer plant explosion in 2013 can injure a large number of people by blast effects, with a similar injury pattern to military or terrorist casualties.

CLASSIFICATION OF BLAST EFFECTS

The effects of an explosive blast are generally grouped into 4 categories (**Table 1**) that are considered separately here.

Primary Blast Effects

Primary blast effects are those caused by the overpressure wave of the explosion. The blast wave propagates in 3 dimensions, and decreases in force as it travels farther from the source. However, when encountering a structure or when confined inside a building, the blast wave can be subject to complex and unpredictable changes in its destructive force,⁴ and proximity to the blast does not always correlate with injury severity.⁵ The orientation of the casualty to the blast (ie, facing toward or sideways) can also influence the injuries received.⁴ Reviews of military casualties from Iraq and Afghanistan reveal more severe primary blast injuries among personnel inside vehicles,⁶ suggesting that armored vehicles may protect against secondary fragmentation damage but still transmit a significant overpressure wave.

Organs frequently injured by primary blast injury (PBI) include the lungs, tympanic membranes (TMs), intestines, and brain. Isolated PBI may not leave any external signs of injury in a casualty, requiring a high index of suspicion to identify these injuries. PBI causes injury primarily in air-filled organs and at air-fluid interfaces. As the blast wave propagates through the casualty, barotrauma or change in pressure at these interfaces causes injury. Solid organs are also susceptible to barotrauma but in general require the casualty to be very close to the center of the blast. Cardiac dysfunction can occur either because of a direct myocardial depressant effect or arrhythmias.⁷⁻⁹ In addition, PBI to vascular endothelium may cause diffuse plasma leakage and resultant hemoconcentration and hypovolemic shock, even in the absence of other injuries causing blood loss.¹⁰

Classically, a ruptured TM was seen as a marker for blast severity, and a normal otoscopic examination was thought to identify a patient at low risk for PBI. This concept has not been supported by data from recent incidents. In a review of injuries from the 2004 Madrid train bombings, only approximately 50% of the casualties had ruptured TMs (although this study did not differentiate between primary and secondary blast injuries).¹¹ In another study, investigators studied a series of military blast casualties in Iraq, and found that only 16% had perforated TMs. When they analyzed injuries that could only be caused by primary blast effects (eg, simple pneumothorax, pulmonary contusion), they still only had 50% with ruptured TMs.¹² Given this, we do not think that a normal otoscopic examination can exclude a significant PBI.

Table 1
Types of blast injuries

Primary	Injuries caused directly by blast overpressure wave
Secondary	Fragmentation injuries
Tertiary	Blunt trauma caused by displacement of the casualty, or structural collapse
Quaternary	Burns, toxic inhalation, chemical exposure, or radiation exposure

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