PULMONARY BLAST INJURY

SUMMARY
Civilian trauma centers are encountering more and more injuries secondary to gunshot wounds and explosions. Healthcare providers should be familiar with the injury patterns and treatments recommended for these specific injuries.

RECOMMENDATIONS

- **Level 1**
  - **None**
- **Level 2**
  - **Low-tidal volume ventilation and permissive hypercapnia are appropriate ventilation strategies for patients with pulmonary blast injury.**
- **Level 3**
  - **The Blast Lung Injury (BLI) Severity Score may be useful to estimate lung dysfunction resulting from blast injury.**
  - **Independent lung ventilation, extracorporeal membrane oxygenation, high frequency jet ventilation/positive pressure ventilation (HFJV/PPV) and inhaled nitric oxide may be considered in patients categorized with severe BLI within the first 24 hours.**

INTRODUCTION
Terror-related attacks are becoming more and more prevalent in the civilian population. As such, it is important for healthcare providers to be educated on the injury patterns and treatment of these injuries. Civilian trauma due to explosions and associated blast waves differs from that encountered in the military due to the lack of protective gear donned by a civilian (1). Explosions can result in both penetrating and blunt traumatic injury with severe morbidity and mortality. Such patients may present with a combination of traumatic mechanisms, further confusing the appropriate work up and treatment (2).

LITERATURE REVIEW
Explosions are created when a chemical reaction transforms a solid or liquid into a gas within a short period of time. This generates a massive release of energy referred to as a “blast wave.” The positive pressure from this wave travels faster than the speed of sound. Effects from the energy wave can be intensified in enclosed spaces and under water due to the reflection of pressure waves off surfaces and/or the conversion of the wave in a substance of different density (i.e., water).

EVIDENCE DEFINITIONS

- **Class I:** Prospective randomized controlled trial.
- **Class II:** Prospective clinical study or retrospective analysis of reliable data. Includes observational, cohort, prevalence, or case control studies.
- **Class III:** Retrospective study. Includes database or registry reviews, large series of case reports, expert opinion.
- **Technology assessment:** A technology study which does not lend itself to classification in the above-mentioned format. Devices are evaluated in terms of their accuracy, reliability, therapeutic potential, or cost effectiveness.

LEVEL OF RECOMMENDATION DEFINITIONS

- **Level 1:** Convincingly justifiable based on available scientific information alone. Usually based on Class I data or strong Class II evidence if randomized testing is inappropriate. Conversely, low quality or contradictory Class I data may be insufficient to support a Level I recommendation.
- **Level 2:** Reasonably justifiable based on available scientific evidence and strongly supported by expert opinion. Usually supported by Class II data or a preponderance of Class III evidence.
- **Level 3:** Supported by available data, but scientific evidence is lacking. Generally supported by Class III data. Useful for educational purposes and in guiding future clinical research.

Three types of forces contribute to the damage inflicted by a blast injury (3):

1) Spalling forces: seen when the wave displaces and fragments one tissue into another, usually higher density into a lower density. An example would be blood displacement from a capillary into an alveoli causing alveolar hemorrhage.
2) Implosion forces: When the blast wave enters the victim, it causes gas to rapidly expand and compress. Barotrauma can be noted from the expanding and collapsing air in the alveoli.
3) Inertia forces: noted when different tissues absorb different amounts of energy causing shearing of tissues. This is most often seen with traumatic amputations of limbs.

Within the lung, these forces combine to damage the architecture of the alveoli and cause pulmonary hemorrhage. Free hemoglobin within the alveoli leads to release of free radicals which work to increase edema and activate the body's inflammatory cascade, leading to acute respiratory distress syndrome (ARDS). When examining lung parenchyma after blast injuries, perivascular edema is noted with extensive alveolar hemorrhage leading to epithelial cell damage and detachment of these cells from the basement membrane (4).

Blast injuries are traditionally classified as primary, secondary, tertiary or quaternary (3):

- Primary blast injuries (PBI) result as an over-exposure to a blast wave. Effects from this injury are most apparent when the energy from the blast travels through organs of different densities; air and tissue or water and air. Examples are noted in pulmonary injuries, injury to tympanic membranes, gastrointestinal contusions and/or perforations, and traumatic amputations
- Secondary blast injuries are penetrating injuries caused by flying debris
- Tertiary blast injuries occur when victims are physically propelled onto a hard surface
- Quaternary blast injuries are all other explosion-related effects including burns, asphyxia, radiation poisoning, toxins, psychological trauma and exacerbation of prior medical conditions

Management of all blast injuries should first follow standard Advanced Trauma Life Support guidelines. Clinically, these patients may present with shortness of breath, cough, chest pain, hemoptysis, cyanosis and tachypnea. Patients may be hypoxic upon arrival, but this is typically manifested later in the hospital course (1). A chest radiograph (CXR) should be obtained upon arrival to the hospital. A "bat wing sign," or pattern of bilateral perihilar shadowing, may be apparent on initial CXR, as well as subcutaneous emphysema, pneumothorax, interstitial emphysema, pneumopericardium, pneumomediastinum, and pneumoperitoneum.

Treatment of blast injuries to the lungs is similar to the treatment of ARDS(5). Fluid resuscitation volumes should be limited. A "lung-protective" strategy, with low tidal volumes and permissive hypercapnia, should be employed to minimize peak and plateau airway pressures. In refractory cases, rescue strategies such as inhaled nitric oxide, inhaled prostaglandins or open-vent strategies may be considered. Pizov et al. advocate the use of a Blast Lung Injury (BLI) Severity Score to guide treatment strategies (6). The score uses three objective signs: hypoxemia, chest radiograph findings and the presence of a bronchopleural fistula to define the severity of the pulmonary injury.

Blast Lung Injury (BLI) Severity Score

	Severe	**Moderate**	**Mild**
PaO_2/FiO_2	<60	60-200	>200
CXR findings	Massive bilateral infiltrates	Bilateral or unilateral infiltrates	Localized lung infiltrates
Bronchial pleural fistula	Yes	Yes/No	No

Fortunately, Hirshberg et al. demonstrated that patients who survive have good long term outcomes as seen in victims of a civilian bus explosion who followed up after one year (7).

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