The Spectrum of Blast Injury

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History

• Halifax, Nova Scotia December 6, 1917
  – Belgian ship Imo collides with French munitions ship Mont Blanc
  – 35 tons of benzene ignite on top deck of the Mont Blanc
  – 15 minutes later the fire ignites 2300 tons of picric acid, 10 tons of gun cotton, 300 rounds of ammunition and 200 tons of TNT
  – 2.5 km of city leveled, 150 tidal wave, 2000 dead, 9000 injured, 20,000 homeless (in a city of 50,000), entire fire department lost

April 16, 1947, Texas City, Texas

• The ship Grand Camp catches fire
• 20 minutes later cargo of ammonium nitrate fertilizer explodes
• A second more powerful blast shortly later followed by a 150 foot tidal wave
• 600 deaths in a city of 16,000—loss of entire fire department
Civilian Casualties due to Blast Injury

- 1970’s: Ireland
- 1980’s-present: Israel
- 2000-present: the entire world

Terrorist Bombing Victims at SZMC Jan 1995-Jan 2004

- 847 victims of bombings
- 14 (1.6%) died during initial resuscitation
- 32 (3.8%) required ICU admission
- 160 (19%) admitted to ward
- 46 Severely Injured Patients

Terrorist Bombing Victims at SZMC Jan 1995-Jan 2004

<table>
<thead>
<tr>
<th>Injury</th>
<th>Closed Space N(%)</th>
<th>Open Space N(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blast Lung</td>
<td>23 (50)</td>
<td>5 (24)</td>
</tr>
<tr>
<td>Burns</td>
<td>14 (30)</td>
<td>4 (19)</td>
</tr>
<tr>
<td>Abd solid organ</td>
<td>7 (15)</td>
<td>5 (24)</td>
</tr>
<tr>
<td>Penetrating GI Injury</td>
<td>3 (6.5)</td>
<td>2 (9.5)</td>
</tr>
<tr>
<td>Intest Blast Injury</td>
<td>1 (2)</td>
<td>0</td>
</tr>
<tr>
<td>Vasc Injury</td>
<td>1 (4)</td>
<td>4 (19)</td>
</tr>
<tr>
<td>Rupt Tymp Membrane</td>
<td>26 (56)</td>
<td>4 (19)</td>
</tr>
</tbody>
</table>

Primary Potential Injuries

- Lung
- Tympanic Membrane
- Intestine
- Ruptured Globe
- Cerebral Concussion

Secondary Potential Injuries

- Penetrating Trauma
- High risk of penetrating eye injury

Tertiary Potential Injuries

- Closed and Open head Injury
- Fractures
- Traumatic Amputations

Quaternary Potential Injuries

- Burns
- Crush Injuries
- Bloodborne Infections
- Smoke/dust inhalation
- Exposure to Nonconventional Weapons

http://www.cdc.gov/masstrauma/preparedness/primer.htm
Primary Blast Injury to Tympanic Membrane

- 18 y.o man presents 1 week after blast injury
- c/o transient high pitched tinnitus
- Intact TM with subepithelial blood vessel rupture and thrombosis

Gadre AK. Ear Nose Throat J 2005;84:686

Blast Injury to Tympanic Membrane

- Symptoms
  - Hearing loss
  - Earache
  - Tinnitus
  - Vertigo
  - otorrhea


Is Isolated Ruptured Tympanic Membrane a Marker for Blast Lung Injury?

- 770 patients injured in 11 terrorist bombings in Israel between 1996-1999
- 145 (18.8%) died; 123 dead at scene, 22 died after hospital admission
- 193 (29.8%) of 647 patients admitted to hospital had primary blast injury
  - 142 with isolated TM perforation
  - 51 with other forms of Primary Blast Injury
- No patient with isolated TM Perforation later developed Blast Lung Injury or Intestinal Perforation


Is Isolated Ruptured Tympanic Membrane a Marker for Blast Lung Injury?

- Prospective Study of 167 Blast Injury Patients admitted over 30 days in Iraq
- 16% (27) had TM perforation
- 13/27 had bilateral TM perforation
- 12/167 had Blast Lung Injury (BLI)
- 6/12 patients with BLI had TM perforation

Is Isolated Ruptured Tympanic Membrane a Marker for Blast Lung Injury?

- TM as a marker for BLI: sensitivity of 50% (95% CI, 22–78%) and specificity of 87% (95% CI, 81–92%).
- Conclusion: TM not an accurate biomarker for Blast Lung Injury


However

- 210 male soldiers studied in Iraq
- 35.2% incidence of TM rupture
- 35.7% incidence of loss of consciousness
- A significant association between loss of consciousness and TM rupture
- Is TM rupture a marker for neurologic injury??


Other Middle Ear Blast Injuries

- Disarticulation of the ossicular chain
- Fracture of the ossicles


Cochlear Injury

- Basilar Membrane most vulnerable to acoustic trauma
- Blast injury can tear the inner and outer hair cells from their supporting cells

258 patients exposed to Blast Injury during Operation Enduring Freedom evaluated at Walter Reed

- More than 50% had significant hearing loss that could not be explained by age
- 32% had tympanic membrane perforation


Pulmonary Blast Injury

Clinical Picture similar to Pulmonary Contusion but
- Usually no rib fractures
- Chest wall tightness
- Sob
- Hemoptyis

Typical CXR findings
- “Butterfly” pattern of infiltrate
- Pneumomediastinum
- Interstitial Pulmonary emphysema
- Pneumothorax
- Hemothorax

Case 1 Primary Blast Injury

- 12 yo girl involved in bus bombing Jan 23, 2004
- Admitted with sob but hemodynamically stable
- CT scan ordered 40 minutes after arrival
- Intubated in CT Scan
- Fresh blood suctioned from ET tube

Case 1

- Infiltrates worsen
- CXR deteriorates
- Hemodynamic instability requires large infusion of crystalloid
- Gas exchange deteriorates, requires FiO2 100% and HFPPV
Case 1

• Patient improves with HFPPV and diuresis
• Develops diplopia for unclear reasons which improves over 2 month period
• Returns to school

Case 2

• 10 days of mechanical ventilation
• 1 month of in hospital rehabilitation
• Prolonged recovery at home

Case 2 Primary and Tertiary Blast Injury

• 73 yo former Pediatric Head Nurse
• Bus explosion Jan 29, 2003
• Admitted with sob, chest pain
• Injuries:
  • Flail chest
  • Pulmonary contusion
  • Fracture right humerus
  • Traumatic bilateral finger amputations
  • Partial thickness facial burns

Significant Risk of Left Sided Air Embolism

• Caused by alveolar-pulmonary venous fistula due to disruption of alveoli due to primary blast injury
• Possible Patent Foramen Ovale
• Risk increased with positive pressure ventilation
• Clinical manifestations
  • Blindness
  • ‘Hemiparesis
  • Paraplegia
  • Acute obstruction of other vascular beds
Evaluation of Patient for Air Embolism

- Fundoscopic Exam – bubbles in retinal artery?
- Echocardiogram
- CT Head
- Most examinations are non-diagnostic

Treatment of Patient with Air Embolus

- Left Decubitus Position, Head Down, Feet Up
- Keep Peak Inspiratory Pressure Low if Patient Requires Mechanical Ventilation
- Hyperbaric Chamber

Case 3 Primary Blast Injury with Air Embolism and ? Intestinal injury

- 14 yo boy admitted in shock, unconscious with pH 7.0 and pCO2 70
- Intubated in ER and moved immediately to RR (secondary triage)
- Resp Status improves
- CT Chest and Abd ok except for pulm blast injury
- CT head ? Air embolus

Case 3 Hospital Course

- Resp Status remains stable
- Mental status begins to improve
- Dense left hemiparesis becomes evident
Case 3

• Condition at discharge:
  - Left hemiparesis
  - Extremely labile

• 2 months later Hemiparesis almost Completely resolved, playing soccer

Summary

• 4 types of Blast Injury
• Most severely injured patients are dead at the scene
• TM perforation common (+/- 30%)
• TM perforation is not a marker for Blast Lung Injury but MAY be a marker for Brain Injury