Mechanisms of Injury

EXPLOSION AND BLAST INJURIES
Outline

• Injury definitions
• Bomb-Injury threat model
• Agent
• Host
• Environment
• Specific examples
• Review
Injury definitions

• **Primary**: blast wave

• **Secondary**: projectile fragments

• **Tertiary**: contact with objects (blunt)

• **Quaternary**: burns and toxins
Bomb-Injury Threat Model

Agent

Host

Environment

Bomb

Size & weight
Explosive choice
Purpose & Source
Delivery system
Adulterants
Tactic

Human
Age, sex, & weight
Fitness, PPE
Nutrition, health
Access to care

Open Space, Confined Space,
Structural Collapse
Reflecting or Shielding surfaces
Building and non-structural debris
Air and liquid hazards

Lee-Davis
Agent

500lbs bomb rigged as IED
Anti-Tank Mine encased in concrete and command detonated via remote control

Artillery shells rigged as IEDs
Explosives

• Chemical compound that is able to release stored energy in the form of rapidly expanding gases
  ─ High Order Explosives (HE)
    • TNT, ammonium nitrate fuel oil, C-4
    • Blast wave
    • Primary blast injury
  ─ Low Order Explosive (LE)
    • Propellants (black powder, pyrotechnics)
    • No blast wave
    • Rare primary blast injury
High explosives

- Stored energy is released rapidly
- Detonation
- Examples: TNT and dynamite
Idealized blast overpressure waveform seen only in high-order explosives (HE)

Horrocks, CL. Blast Injuries: Biophysics, Pathophysiology and Management Principles.
Fig. 1. Pressure-time histogram of an ideal air blast wave as it would occur in a free field environment. Impulse is the integral of pressure over time P/dt. Positive phase, is the pressure above ambient; negative phase, is the pressure below ambient. Inset: histogram of an actual complex blast wave recorded inside an armored vehicle penetrated by a shaped-charge munition (modified from Stuhmiller et al., 1991).
• Nuclear video
Low explosives

• Stored energy is released slowly
• Combustion or deflagration
• Examples: gun powder, fuel
• No blast wave or overpressurization
• Injury results from:
  – Thermal burns,
  – Ballistic (shrapnel)
  – Suffocation (fumes and toxins)
Host

- Age
- Sex
- Height
- Medical history
- Access to care
Environment

- Open space
- Enclosed or confined space
- Structural collapse
- Underwater
Open space

- Potential for shrapnel to travel a large distance (>100 m)
- Less primary blast injuries
Enclosed space

- Increased mortality
- Increased blast pressure
- Complicated rescue
Structural collapse

- Increased mortality from primary blast wave as well as from tertiary and quaternary injuries
- Crush syndrome
Who is this?
Where is this?
DIAGRAM SHOWING RYDER TRUCK LOCATION AND BOMB CRATER

SOURCE: OKLA. BOMBING INVESTIGATION COMMITTEE FINAL REPORT
High explosives

- Stored energy is released rapidly
- Detonation
- Examples: TNT and dynamite, and ANFO!
Table 4 Impact of Building Collapse on Outcome in Oklahoma City Terrorist Bombing, 1995*

<table>
<thead>
<tr>
<th>Casualty Location</th>
<th>No. of Casualties</th>
<th>No. of Dead (%)</th>
<th>No. of Survivors</th>
<th>No. of Survivors Hospitalized (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collapsed</td>
<td>175</td>
<td>153 (87)</td>
<td>22</td>
<td>18 (82)</td>
</tr>
<tr>
<td>Uncollapsed</td>
<td>186</td>
<td>10 (5)</td>
<td>176</td>
<td>32 (18)</td>
</tr>
<tr>
<td>Total</td>
<td>361</td>
<td>163 (45)</td>
<td>198</td>
<td>50 (25)</td>
</tr>
</tbody>
</table>

* Includes only 361 casualties inside the Murrah Building, stratified by portion of building in which they were located. From Mallone et al., 1996.36


Review

• Blasts occur from various causes, including intentional causes

• High explosives detonate

• Low explosives combust or deflagrate
Review

• High explosive blasts cause a supersonic blast wave, which is a pressure wave that travels ahead of the other effects (heat and fragments) and causes PRIMARY blast injury.
Review

• Both High and low order explosions cause fragmentation and penetrating injury, known as SECONDARY injury
Review

- Both high and low order explosions can throw people into objects, throw objects into people, or cause structural collapse, causing **TERTIARY** injury
Review

- Explosions cause heat injury (burns) and create toxic products (carbon monoxide, cyanide, etc) that cause QUATERNARY injury
Review

• The pattern of injury is predictable given knowledge of:
  – Agent
  – Host
  – Environment
Questions or comments?