Mechanisms of Injury
ADVANCED EXPLOSIONS & BLAST INJURIES

Outline

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

- "There can be only 4"
- Water – quick propagation of blast
- Distance – further away is better
- Blast site – open/closed²
- Reflection – bounce off a wall


Injury Definitions

- Primary: blast wave
- Secondary: projectile fragments
- Tertiary: contact with objects (blunt)
- Quaternary: burns and toxins

²Zuckerman S. Experimental study of blast injuries to the lungs. Lancet 1940;i:219-24

Immediate Effects of Blast and Explosions

- Primary - direct effects (e.g., overpressurization and underpressurization)
  - Rupture of tympanic membranes
  - Pulmonary damage
  - Rupture of hollow viscera
- Secondary
  - Penetrating trauma
  - Fragmentation injuries
Immediate Effects of Blast and Explosions

- Tertiary - effects of structural collapse and of persons being thrown by the blast wind
  - Crush injuries and blunt trauma
  - Penetrating or blunt trauma
  - Fractures and traumatic amputations
  - Open or closed brain injuries
- Quaternary - burn, asphyxia, and exposure to toxic inhalants
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-Order Explosives

- Stored energy is released rapidly
- Detonation
- Examples: TNT, dynamite, shaped charges

Shaped charges

- Shaped charges\(^1\),\(^2\)
  - Used to focus effect of explosive’s energy
- What is an EFP?\(^1\),\(^2\)
  - Explosively formed Projector/Penetrator
  - Instead of a cone, it has linear shaped dish
- Why do we care about it?
  - Can penetrate military armor
  - Few countermeasures available
  - Used in IEDs

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\(^2\)Explosively Formed Penetrators
Shaped Charges

Idealized blast overpressure waveform seen only in high-order explosives (HE)

- Positive phase overpressure duration
- Negative phase
- Vacuum

Detonation
Shock wave

*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 shot of debris (modified from Stuhlmiller 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)

Blast Wind

- Subsonic pressure front
- Generated by high and low-order explosives
- Area of low pressure
- Causes debris and fragments to rush back towards the original explosion

Nevada Atomic Bomb Testing Site - 1955

Film and images at 1 km (0.6 mile) from ~16kT yields
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


Blast Wave in Enclosed Space

- Wave reflects over surfaces:
  - Creates complex waves
    - Greater in amplitude
    - Expose the body for a longer period

Blast Wave in Enclosed Space

Structural Collapse

- Increased mortality from primary blast wave as well as from tertiary and quaternary injuries
- Crush syndrome
Who is this?

Where is this?