Clinical Aspects

EXPLOSION AND BLAST INJURIES
Outline

• Types of injuries seen
• Injury characterization
• Specific Injuries
  – Primary
  – Secondary
  – Tertiary
  – Quaternary
Madrid Bombing - Injuries

- Rupture of the tympanic membranes occurred in 99 of 243 victims
- Chest injuries in 97/243 victims
- Shrapnel wounds in 89/243
- Fracture in 44
- Burns in 45
- Eye injuries in 41
- Abdominal injuries in 12
- Traumatic amputations in 5
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
Tertiary Blast Injury (Injuries due to impact with another object)

Secondary Blast Injury (Injuries due to missiles being propelled by blast force)

Primary Blast Injury (Injuries due to the blast wave itself)
Primary Blast Injuries

• Result from over-pressurization or under-pressurization relative to atmospheric pressure

• Result from the interaction of high frequency stress waves and low frequency shear forces
Primary Blast Injuries

• Affect air-filled organs or air-fluid interfaces

• Rupture of tympanic membranes, pulmonary injury, air embolization and rupture of hollow viscera are the most common patterns
Tympanic Membrane Rupture

- Occurs at the lowest pressure (5 psi)
- May be bilateral
- May be the earliest sign to look for
  - Deafness, tinnitus and vertigo
- If more severe, may cause dislocation of the oval, round window or the ossicles
  - Permanent hearing loss
- Other organs need higher pressures (56-76 psi) so if the TM is intact, they are unlikely
Tympanic Membrane Rupture
Normal and Perforated Right Tympanic Membranes

The drawing of a traumatic perforation shows an irregular margin or rim with blood or a blood clot, and the drawing of a permanent central perforation shows a tympanocele.
Pulmonary Injuries

- Second most common primary blast injury
- Hemorrhage
  - Pulmonary contusion (appearing as a bihilar "butterfly" pattern on chest radiographs)
  - Pneumothorax
  - Hemothorax
  - Pneumomediastinum
  - Subcutaneous emphysema
The roentgenogram of a soldier who was injured by blast shows bilateral infiltrates from pulmonary edema, with no sequelae.

- USA and Munitions Effectiveness Team

Image credits:
Pulmonary Injuries

• Onset of symptoms is commonly within minutes
  – Controversial

• Early onset pulmonary edema carries a grave prognosis
Body Armor

- Protects from secondary blast injuries
- Does not protect from primary blast injury
Kevlar Helmet
TM Perforation - Pulmonary Injury

• Among 17 critically ill victims with pulmonary injuries from the blast:
  – 13 had ruptured tympanic membranes and 4 did not

• Rupture of tympanic membranes occurred in 18 of 27 critically injured victims
  – 17 of these were bilateral

_Data from Madrid_
Screening

- 647 survivors of explosions on buses used immediate radiography of the chest to screen for pulmonary injuries from the blasts

- Primary injuries, in some form, were found in 193 persons:
  - 142 had isolated perforation of the eardrum

_Data from Israel_
Screening

• 51 had other forms of primary blast injuries:
  – 18 with isolated pulmonary injuries
  – 31 with combined otic and pulmonary injuries
  – Two with intestinal injuries
Visceral Injury

- Visceral injury is third most common primary blast injury
- Rupture of the colon and, less frequently, the small intestine may occur as an immediate result of a blast
- Mesenteric ischemia or infarct can cause delayed rupture of the large or the small intestine; these injuries are difficult to detect initially
Visceral Injuries

- The ileocecal area is the most vulnerable
  - Accumulates gas
- Observed findings
  - Hemorrhages
  - Edema
  - Perforations
  - Lacerations

Fig. 4. Gross severe pathological changes predominately to the colon and to a lesser extent to the spiralis of a sheep necropsied at 24 h post BOP exposure demonstrating confluent ecchymosis (→), thrombus formation and perforation (⇒).
Other Injuries

- Serous retinitis
- Concussion
- Air embolism may be seen and can present as stroke, MI, acute abdomen, blindness, deafness, spinal cord injury, or claudication
Ruptured Globes
Secondary Injuries

• Penetrating injuries from:
  – Primary fragments (fragments that are part of the weapon)
  – Secondary fragments (those that result from the explosion)

Ocular war injuries in Iraq are common
Figure 1—Photograph of the patient’s abdomen showing a small subxiphoid entry wound

Figure 2—Chest radiograph showing a nail embedded in the patient’s left lung
Tertiary Injuries

• Caused by trauma from falling objects or from bodies being thrown against other objects
  – Blunt and penetrating injuries
  – Crush syndrome and secondary rhabdomyolysis
  – Open or closed head injuries
Crush Syndrome

- Entrapment increases mortality

- Rhabdomyolysis:
  Myoglobinuric renal failure and hyperkalemia
Pelvic Fractures
# Crush Syndrome-Earthquakes

<table>
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<th>Location and Year</th>
<th>Death</th>
<th>Crush Syndrome</th>
<th>Dialysis</th>
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<td>Total</td>
<td>&gt;217,000</td>
<td>&gt;1900</td>
<td>&gt;1200</td>
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\*overall number of crush victims
Rhabdomyolysis

- Secondary complication of crush syndrome
- Myoglobinurea and CK elevation
Quaternary Injuries

- Burns (chemical or thermal)
- Toxic inhalation of carbon monoxide or hydrogen cyanide gas
- Exposure to radiation: ARS and Internal Contamination
- Inhalation of dust containing coal or asbestos
- Exacerbation of chronic illnesses
Carbon monoxide-Mechanism

- Binds hemoglobin to form carboxyhemoglobin that is unable to carry oxygen
- Uncouples oxidative phosphorylation
Carbon Monoxide-Clinical

- Most common presentation:
  - Flu-like illness
- CNS
- CV
Carbon Monoxide-Labs

- Carboxyhemoglobin level
- Creatine kinase
- EKG, CXR
Long-term Effects
Hydrogen Cyanide-Mechanism

- Inhibits cytochrome oxidase and uncouples oxidative phosphorylation
- Cells are unable to use oxygen
- Aneorobic metabolism prevails
Hydrogen Cyanide-Clinical

- Clinical:
  - CNS
  - CV
  - Bitter almond: only 60% of population can detect it.
  - Cherry red skin, fundoscopic exam
Hydrogen Cyanide-Labs

- Lactic acidosis
- Elevated venous O2 saturation
  - >90%
- Low O2 extraction
Exacerbation of Chronic Illnesses

- Asthma and COPD
- Diabetes Mellitus
- Hypertension
- Coronary artery disease
- Peptic ulcer disease
- Alcohol and substance abuse
- Mental health
Review Questions

• What factors influence the types of blast injury?
  – Agent
  – Host
  – Environment
Review question

• What are the types of blast injury?
  – Primary (blast wave)
  – Secondary (ballistic)
  – Tertiary (being thrown / falling objects)
  – Quaternary (burns, toxins)
Review question

• What is the most common primary blast injury?
  – Ruptured Tympanic Membrane
Review question

• Can tympanic membrane rupture be used to screen for other injury?

  – Not reliably