Management of Blast Injuries

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Aggression on Lebanon
2006

Aggression on Gaza
2009

Civil war in Syria
2012

Civil war in Yemen
2016 - 2017
Disclosure

- Nothing to disclose
Objectives

• Explain the Physics of Blast and Mechanisms of its Injury
• Describe the Clinical Aspects of Blast Injury
• Describe Basic Treatment of some Blast Injuries
What is different about blasts?

Physics & Mechanisms
Classification of Explosives

• High Order (HE) Explosive
  • Supersonic explosion: high pressure shock wave
  • Ex. TNT, C-4, Semtex, dynamite

• Low Order (LE) Explosive
  • Subsonic explosion: lacks over-pressurization wave
  • Ex. Molotov cocktails, fire works etc

• Manufactured (ME) Explosive
  • Most often supersonic explosion: high pressure shock wave
  • Standard military-issued quality-tested weapon
“High Order Explosive”

• When a high explosive detonates, it is converted instantaneously into a gas at high pressure and temperature

• The expansion of these gases creates the blast (shock) wave
Shock front (wave)

Edge of explosive products
Physics of Blast Injuries

- Blast (shock) wave
  - Pressure transmitted radially from source into surrounding medium
- Positive phase
- Negative phase
- Mass movement of wind (blast wind)
SECONDARY MISSILE ETC... BEING PROPELLED

TERTIARY IMPACT
HARD SURFACE
MULTIPLE INJURIES POSSIBLE

PRIMARY BLAST FORCE
INJURIES:
1. EARS
2. LUNGS
3. G.I. TRACT
Physics of Blast Injuries

• Distance and type of explosion predict injury severity and type
  • Confined space vs. open space

• Blast wave reflected by solid surfaces

• Intensity of explosion pressure wave declines with cubed root of distance away from explosive
  • Standing at 3m has 9x greater pressure than if at 6m
Underwater Blast Injury

• More devastating at a greater distance
  • Pressure wave travels much faster in water
  • Force does not dissipate as quickly
    • Underwater exposure to the explosion of a charge causes death at 3x farther than the lethal range in air
Types of Blast Injuries

• Primary: Due to direct effect of pressure (HE + ME)

• Secondary: Due to effect of projectiles from explosion

• Tertiary: Due to structural collapse and from persons being thrown from the blast wind

• Quaternary: Burns, inhalation injury, exacerbations of chronic disease
Primary Blast Injury

- Over-pressurization wave / Barotrauma
- Compression of surrounding air or water
- Differential pressures at interfaces
Primary Blast Injury

• How will this injure tissue???
Primary Blast Injury

- Differential pressures in tissues
  - Organ distortion
  - Tensile strength of the tissue is exceeded
  - Tissue tearing

- Most commonly involve air-filled organs and air-fluid interfaces
  - Middle ear
  - Lungs
  - Gastrointestinal tract
Secondary Blast Injury

• Due to flying debris and fragments

• Penetrating and/or blunt injuries
  • Leading cause of death except in cases of major building collapse

• Wounds grossly contaminated
Tertiary Blast Injury

• Victim thrown into fixed objects by wind of explosions

• Structural collapse and fragmentation of building and vehicles

• Structural collapse may cause extensive blunt trauma
Quaternary Blast Injuries

- Explosion related injuries
  - Burns (chemical and thermal)
  - Toxic inhalation
  - Radiation exposure
  - Asphyxiation (carbon monoxide and cyanide)

- Exacerbations of preexisting conditions, such as asthma, COPD, etc.
Clinical Aspects & Treatment of Blast Injury
Pattern of Blast Injuries

• Ear Injury
• Blast lung
• Abdominal Injury
• Eye Injury
• Traumatic brain injury (TBI)
• Amputations
• Penetrating Injury
• Blunt Injury
• Burn Injury
• Arterial Gas Embolism - Sudden death!!
Ear Injury

• Tympanic Membrane (TM): most frequently injured by blast mostly due to Primary Blast
  • TM rupture
  • Ossicle dislocation
  • Disruption of oval or round window

• TM rupture is sensitive marker, but absence does not exclude other organ injury

Eardrum Perforation in Explosion Survivors: Is It a Marker of Pulmonary Blast Injury?
Leibovici D et al.
TM Injury

• Otologic exam and audiometry for all

• Symptoms:
  • hearing loss
  • Tinnitus
  • Vertigo
  • bleeding from external canal
TM Injury

• Most resolve spontaneously

• Avoid irrigating, probing the auditory canal or swimming

• Refer to ENT if no healing or complications occur

• Steroids - helpful in some cases?

• Beware Neomycin
Blast Lung

• Lung: next most frequently injured by blast

• Most common fatal primary blast injury among initial survivors
Blast Lung

- Pulmonary barotrauma includes
  - Pulmonary contusions
  - Systemic air embolism
  - Free radical associated injuries
    - Thrombosis
    - Disseminated Intravascular Coagulation (DIC)
Blast Lung

• Clinical triad of apnea, bradycardia, and hypotension

• Signs usually at initial presentation but may manifest as late as 48 hours after explosion

• Should be suspected if dyspnea, cough, hemoptysis, or chest pain

• Keep a high level of suspicion!
Blast Lung

• Radiographic findings
  • Bihilar “butterfly” pattern
  • Pneumothorax or hemothorax
  • Pneumomediastinum
  • subcutaneous emphysema
Blast Lung

• Prophylactic chest tube before general anesthesia and air transport if blast lung suspected
Blast Lung

- High inspiratory pressures increase risk of air embolism and pneumothorax
  - Ventilation should use limited inspiratory pressures
  - Permissive hypercapnia
  - High frequency ventilation may be of value
Abdominal Injury
Abdominal Injury

• Hemorrhage, perforation and/or ischemia
Abdominal Injury

• Colon – visceral organ most frequently affected

• Mesenteric ischemia from gas embolism may cause delayed rupture of large or small intestine

• Solid organ injury secondary to blunt trauma but less common

• More common in underwater blasts
Abdominal Injury

- Acute/Delayed perforation of the bowel
  - No obvious external wound – easily missed
  - Early hemorrhage
  - Delayed sepsis

- Patho-physiology
  - Mesenteric tears
  - Hematomata in bowel wall
  - Intraluminal hemorrhage
  - Delayed perforation up to 8 days after injury
Abdominal Injury

• Serial abdominal examinations

• Serial hematocrit determinations

• Diagnostic studies
  • CT
  • Ultrasonography
  • (Peritoneal lavage)
Eye Injury

• Circa 10 - 30% of blast victims will have significant eye injuries

• Globe rupture, serous retinitis, hyphema, lid laceration, traumatic cataracts, injury to optic nerve
Eye Injury

• Objects penetrating eye should not be removed in an emergency setting
  • Cover affected eye with a paper cup that will not exert pressure on the globe
  • Remove object in operating room under controlled conditions
  • Refer patient to ophthalmology for definitive treatment
TBI

- Blast induced concussion
- Barotrauma of gas embolism
- Penetrating head injury
- Coup-contrecoup injury
Penetrating Injury

• Due to flying debris and bomb fragments
• Penetrating ballistic or blunt injuries
  • Leading cause of death in military and civilian attacks except in cases of major building collapse
  • Wounds grossly contaminated
    • Consider delayed primary closure and tetanus vaccinations!
Amputations

- Due to Primary Blast Injury
- Due to Secondary Blast Injury
- Due to Tertiary Blast Injury
- Delayed primary closure
- Tetanus vaccinations!
Crush Syndrome

• Crush syndrome

  • Damage to muscles and subsequent release of myoglobin, urates, potassium, and phosphates

  • Oliguric renal failure

  • Hydration and alkalinization!
Compartment Syndrome

- Compartment syndrome
  - Edematous muscle in an inelastic sheath promotes local ischemia, further swelling, increased compartment pressures, decreased tissue perfusion, and further ischemia
  - Fasciotomy!
Burn Injury

• Cover burns to minimize heat and fluid loss
Burn Injury

• **White Phosphorous burns require special management**
  • Copious lavage and removal or particles and debris
  • Rinse with 1% copper sulfate solution
    • Combines with phosphorous particles and impedes further combustion
  • Cardiac monitor
    • Hypokalemia and hyperphosphateemia common
  • Use moistened face masks to protect from phosphorous pentoxide gas exposure
  • Avoid use of flammable anesthetic agents and excessive oxygen
Arterial Gas Embolism (AGE)

• Recompression with 100% oxygen

• Left lateral recumbent position
Arterial Gas Embolism (AGE)

• Hyperbaric oxygen (HBO) is definitive
  • Transfer may be necessary

• Aspirin may be helpful in AGE
  • May reduce inflammation-mediated injury in pulmonary barotrauma
  • beware bleeding risk!
General Considerations

• If ruptured TM, chest radiography and eight hour observation recommended
  • Primary blast injury notorious for delayed presentation

• Pulse oximetry
  • Decreased oxygen saturation signals early blast lung even before symptoms

• Surgery should be postponed 24 - 48 hours whenever possible
General Considerations

• Often mass-casualty situation

• Half of all initial casualties seek medical care over first hour

• Most severely injured arrive after less injured
Special Considerations for Treatment of Blast Injury
Special Considerations

• Potential intraoperative and post-resuscitation complications
  • Occult pneumothorax
  • Occult compartment syndrome
  • Hyperkalemia
    • Crush syndrome
    • Rhabdomyolysis
Special Considerations

• Pregnancy
  • Direct injury to fetus is uncommon
  • Fetus protected by amniotic fluid

• Fetal attachment to placenta is tenuous
  • Risk for placental abruption

• If blast in second or third trimester admit for fetal monitoring
 Guidelines for Disposition

• **Low risk:** may be discharged with strict precautions after four hours of observation:
  • Persons exposed to open-space explosions with no apparent significant injury, normal vital signs and unremarkable lung and abdominal examination

• **Moderate risk:** should be observed for longer periods of time for delayed complications:
  • Persons exposed to closed-space explosion or in-water explosions
  • Persons with TM rupture
Thank you for listening

Don't dawdle, prompt action saves lives!
Fawzi al-Ayoubi 2017