COORDINATED EFFORTS OF VHA, DOD AND USUHS TO DEVELOP EDUCATIONAL MATERIALS: PL 107-287

*Offices of PCS and OPHEH*

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Blasts and explosions: physical, medical, and triage considerations

Relationships to emergency caches
TBI
Program relationships
Future Programs
GOALS of PROGRAM

• Understand the mechanisms of blasts and blast injuries
  – Types of explosions
• Understand the medical consequences and syndromes from blast injury
  – Types and classification of injuries
• Be able to apply a triage algorithm to blast injury
  – Triage algorithm
• Other treatment considerations
Explosive Effects

- Blast Pressure Wave
  - Over-pressure
  - Under-pressure
- Fragment effect
- Thermal (incendiary) effect
- Secondary effects
  - Seismic
  - Reflection
Explosive Effects

Blast Pressure Wave

A: time zero: begin of explosion
B: end of over-pressurization wave
C: end of underpressurization wave
B': end of over-pressurization wave for enhanced blast devices
C': end of underpressurization wave for enhanced blast devices

1 psi: threshold for tympanic membrane rupture
2 psi: threshold for pulmonary injury

Atmospheric pressure

X-axis: time
Y-axis: pressure
Explosion

Compressed Gas

Blast Wave

Volume 10 times Greater

(3000 to 8000 m/sec)

Pressure

Time

Atmospheric Pressure
Hopkinson’s Rule

- Peak overpressure directly related to the energy of the blast and inversely proportional to the cube of the distance from its epicenter
Blast Effects

Blast Wave

- Shock Wave Front
- Blast Wind (dynamic pressure)

Hydrostatic Pressure

Fireball - Thermal Output (heat)
Blast Injuries

- **Primary Blast Injuries**
  - Direct effect of blast wave

- **Secondary Blast Injuries**
  - Objects strike individual

- **Tertiary Blast Injuries**
  - Individual strikes objects

- **Quaternary Blast Injuries**
  - Other effects – burns, infections, crush injuries, delayed collapse
INJURY DISTRIBUTION

• Conventional explosive
  – Blunt trauma
  – Penetrating trauma
  – Inhalation injury
  – Thermal injury / Burns
  – Relatively less primary blast injury

• Enhanced blast devices / vehicles / enclosed spaces
  – Primary blast injury (pressure-related effects) predominate over blunt trauma
“ABC” evaluation for life threatening injuries

No obvious injuries

Otoscopic Exam

+  
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<th>Observe</th>
<th>O2 Sat 6-8 hours</th>
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Obvious Injuries

-  

Treat Injuries as usual

Release

+  

Injury RX and blast observation (pulmonary/visceral)

Triage Algorithm
Figure 1. 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.
Primary Blast Injuries

- **Occurs most frequently in:**
  - Middle ear
  - Lungs
  - Large Bowel

- **Results from:**
  - Blast wave contact (dynamic pressure changes) at air-water interfaces
  - Blast loading
    - High frequency stress wave
    - Low frequency shear wave

*Primary blast injuries occur most frequently in air-filled organs, and results from blast wave dynamic pressure changes at air-fluid interfaces*
Primary Blast Injuries

• Ear
  – TM ruptures at 1-8 psi dynamic overpressure
  – Temporary neuropraxia of receptor organs
  – Dislodgement of ossicles may occur

• Lung
  – Pulmonary contusions – multifocal hemorrhages
  – Pulmonary C-fiber receptor injury causes vagal nerve-mediated cardiogenic shock
  – Other injuries: hemothoraces, pneumothoraces, traumatic emphysema, AV fistuaste, pulmonary barotrauma, venous air emboli
Primary Blast Injuries

- **Gastrointestinal Tract**
  - Primarily in colon
  - Rupture
    - Usually acutely
    - Delayed due to ischemia
  - Tension pneumoperitoneum
  - Solid organ subcapsular petechiae

- **Head/Neck**
  - Concussion
Secondary/Tertiary Blast Injuries

Fragments
New Wounds to New Surgeons

Vietnam - Same as today
Crush Syndrome

• A condition resulting from damage to the renal tubules in kidneys following severe injury to muscle tissue in crushing accidents.

• Edema
• Oliguria
• CK > 25,000
Compartment Syndrome

- Perfusion pressure < tissue pressure in a closed anatomic space.
- Left untreated:  
  - Tissue necrosis  
  - Functional impairment  
  - Renal failure  
  - Death  
- Sites: hand, forearm, upper arm, abdomen, buttock, and entire lower extremity.
Compartment Syndrome

- 69% associated with fracture
- 1st signs: pain on passive movement and swelling
- Diagnosis: 5 Ps
  - Pain, paresthesia, pallor, poikilothermia, pulselessness
- Treatment:
  - Elevation
  - Fasciotomy
  - Mannitol?
  - HBO?
TREATMENT PRIORITIES

On-site considerations

• Impalement
  – Penetration by flying objects and fragments
  – Don’t remove
  – Cover and, if possible, stabilize *in situ* to prevent worsening damage

• Burns – cover (relatively clean materials)
  – To prevent further gross contamination
  – To prevent heat loss

• Transportation / fractures
  – Consider splinting long-bone fractures
Diagnosis
Physical examination

- Frothy sputum
  - Early pulmonary edema from primary blast injury grim prognosis, may be triage marker, the earlier it happens the worse the prognosis

- Tympanic Membrane
  - Marker for blast overpressure
  - In the absence of a ruptured TM, the risk of hollow viscous injury is low

- Fragment wounds
  - small external wounds may mask significant internal damage

- Signs of internal bleeding
Treatment Considerations

- Usual surgical approaches for trauma
- Observation for pulmonary blast injury
  - TM rupture a marker
  - Follow O2 Sat for 6-8 hours
- Pulmonary blast injury
  - Limit fluids
  - Ventilator support with limited inspiratory pressure and PEEP.
Treatment Considerations

- **Hollow viscus injury**
  - Presentation may be delayed for several days
  - Peritoneal signs may be subtle in those with other injuries
  - In MasCal situation, selected patients without other injuries may be discharged with appropriate warnings after observation for pulmonary injury.
Crush Syndrome

• Treatment
  – Look for associated injuries
  – Fluids
    • Monitor CVP, UO (100 mL/hour)
  – Alkalization of urine – pH 6.5-7.4
    • NaHCO₃ (1 amp in 1 L of ½ NS)
  – Diuresis
    • Mannitol (maximum 200 g.day) after normal CVP
Basic Cache Additions

- Fluid resuscitation: lactated ringers (other colloid type)
- Delete albumin; whole blood capability
- HemCon bandage; tourniquets
- Burn transport dressings
- Otoscopes and batteries
- Respirators (number and operation)
- Satellite telephones
Stop the Bleeding!!
The plan is nothing, planning is everything
-D. Eisenhower

• The planning process helps all involved to understand the options and flexibly adapt to different circumstances
TYPES OF HEAD INJURY

• CLOSED: DIRECT BLOW: CONCUSSION, HEMATOMA, DIFFUSE
• CLOSED: INDIRECT PRIMARY BLAST: AGE, Pressure transmission: Possibly more common with body armor.
• OPEN: MAXILLOFACIAL; OCULAR
• OPEN: SKULL AND BRAIN LOSS
• PENETRATING: fragments (some very small!)
TREATMENT PRIORITIES

DIAGNOSIS: CT SCAN ASAP


CONCUSSION 23%, Fx depressed fx: 9%
Extracere Hematoma 17%, contusion 17%
Intracere hematoma 11%, Diffuse ax 22%

High proportion diffuse brain injury due to side mines and IEDs a marker of this current conflict
Brain Injuries - Etiology

- Petchial hemorrhage and edema caused by rapid decrease in venous pressure following compression of thoracic and abdominal venous reservoir by the pressure wave.
- With transmission of pressure into the cerebral venous system small blood vessels rupture.
- Acute gas embolism with associated lung injury.
ETIOLOGY

• TBI: NOT A SINGLE ENTITY
Monitoring Strategies

- Oxygen delivery: jugular PO2, Clark electrode
- Serial transcranial Doppler for flow
- Swelling and ICP: Becker bolt
- Systemic biochemical markers include:
  - Neuron specific enolase (axonal)
  - S-100 protein
  - CSF: inflammatory cytokines
Immediate treatment

- Observe concussion level 2-3 AAN CI

Acute diffuse injury: control emergence: excitatory phase; **Bed at 30 degree Gatch**, Beta blockers, pressure monitoring, edema control, steroids

**Specific Neurosurgical interventions.**

Otic skull base: antibiotics and steroids. Late surgery TM and nerve decompression

**AGE:** Hyperbaric RX mentioned: navy input
Research on TBI

- NABISH: pediatric trauma: hypothermia to 91.4 F
- Novel dipetides (Cernak et al JCBFM 2003)
- NINDS: Magnesium sulfate within 8 hours
- Steroids: unproven for TBI but still used
Late considerations

- Recognition of patterns of CNS late effects in survivors of extreme injuries
- Body armor and improved resuscitation
- Need for proactive immediate conservative and surgical Rx
- Need for more research on Blast Injury
Triage

• Indication
  – When demand outstrips resources (Mass Casualty situation definitions)

• Goals
  – To identify patients salvageable with resources at hand

• Quickly sort patients with minimal equipment. Portal otoscopy will be useful
Blast triage: critical elements

- Tympanic membrane rupture
  - A sentinel for the possibility of primary blast injury (pulmonary or visceral)
  - Monitor $O_2$ 6-8 hours
- Location at blast may not predict severity due to reflected pressure waves and other factors
- Ascertaining type of explosion may guide triage