

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

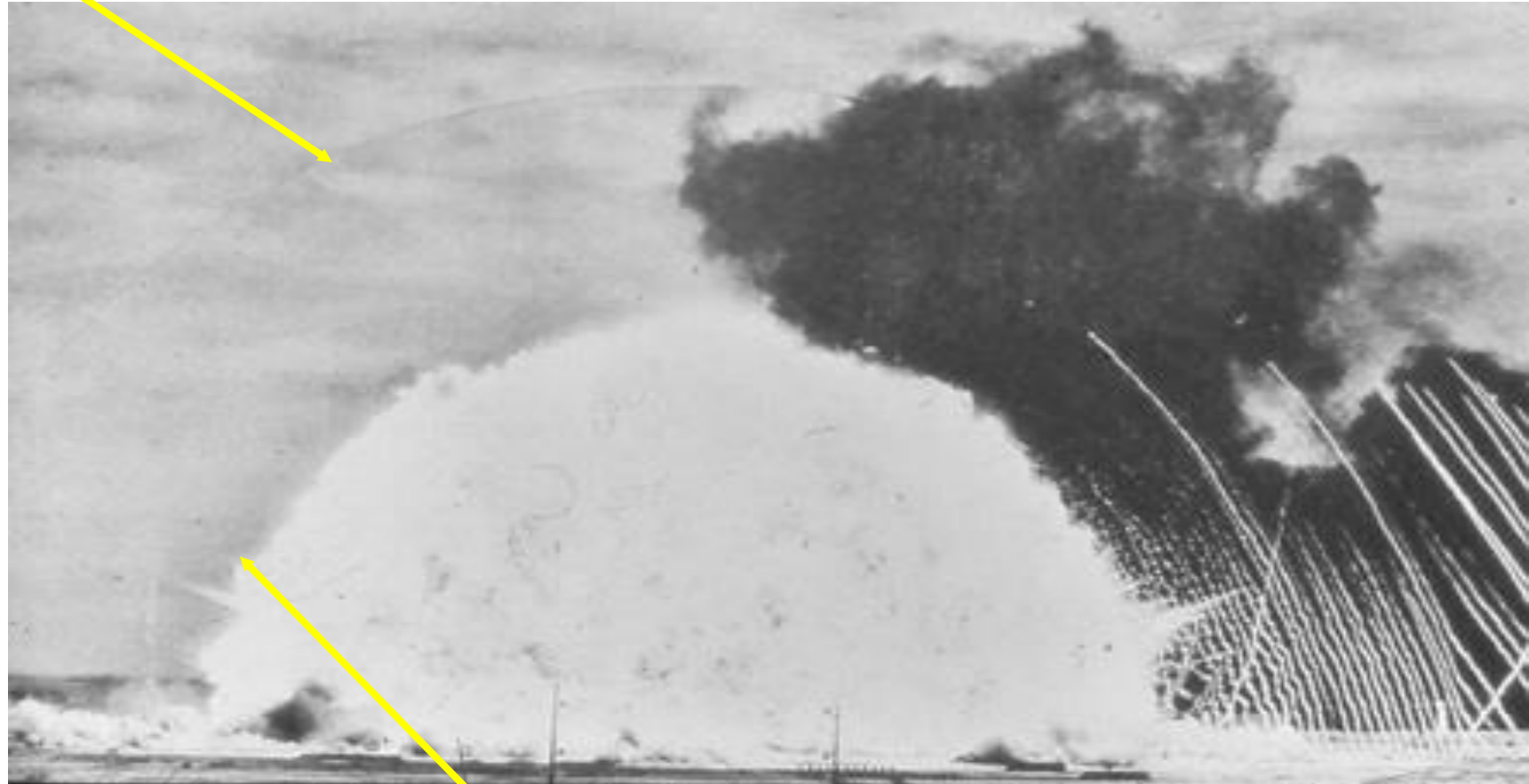
Classification of Explosives

- 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

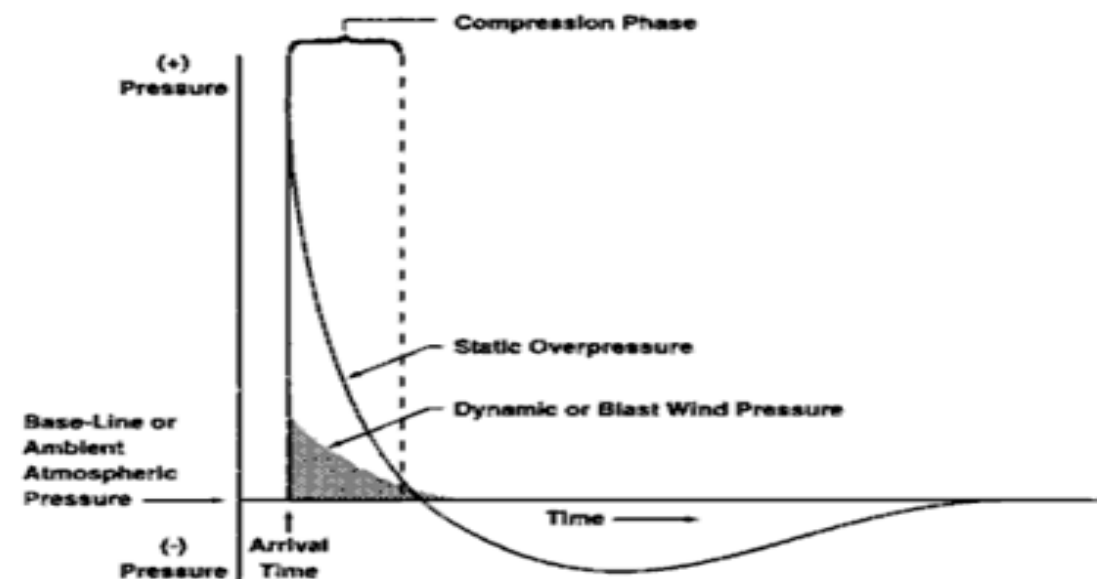
Shock front (wave)

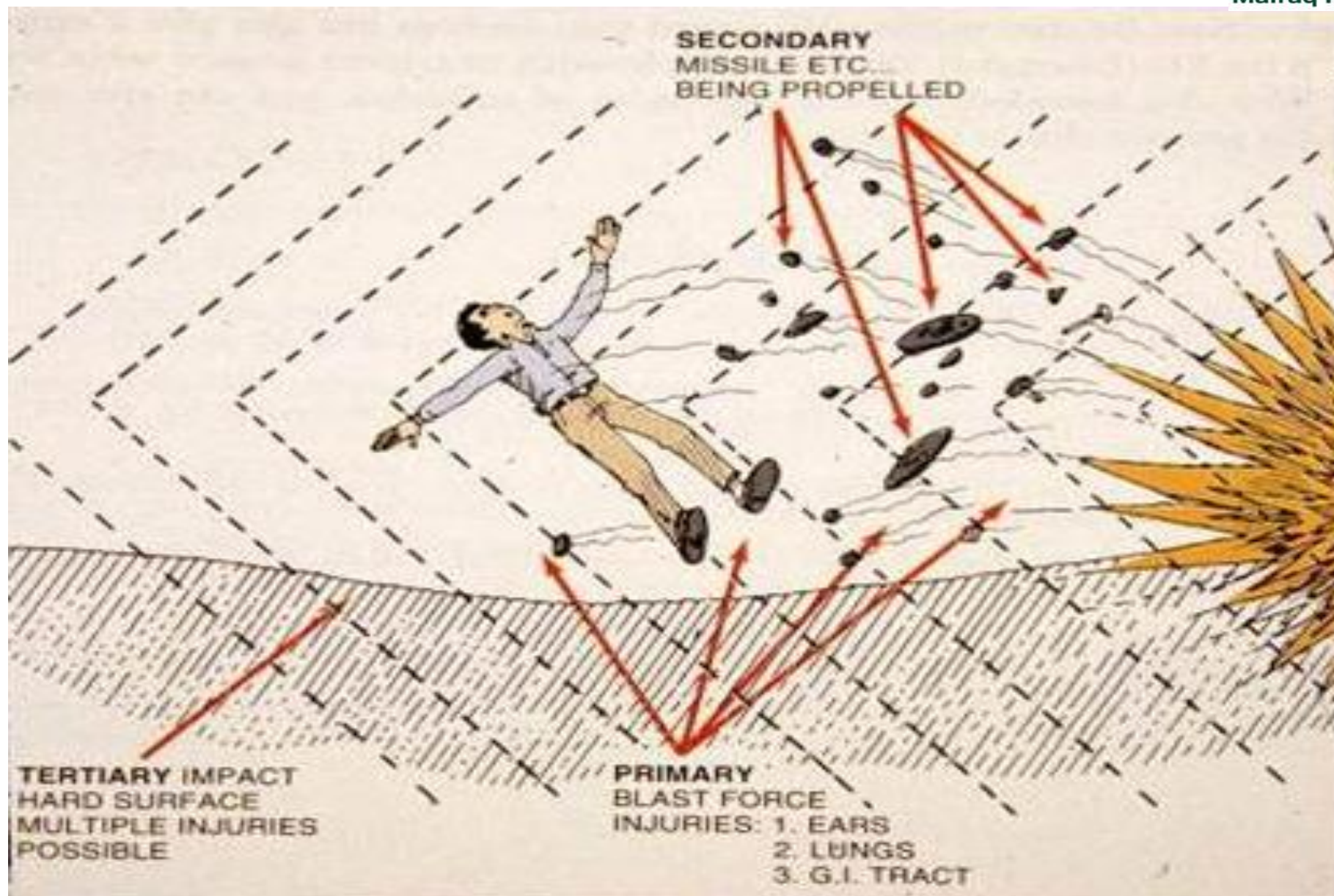


Edge of explosive products

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)





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.

Ann Emerg Med 1999;34: 168 - 172.

TM Injury

- Otologic exam and audiometry for all
- Symptoms:
 - hearing loss
 - Tinnitus
 - Vertigo
 - bleeding from external canal

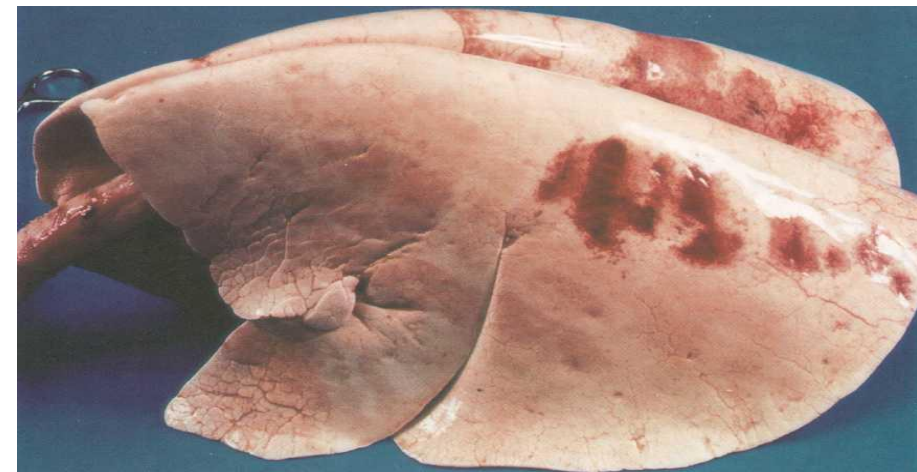


TM Injury

- 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

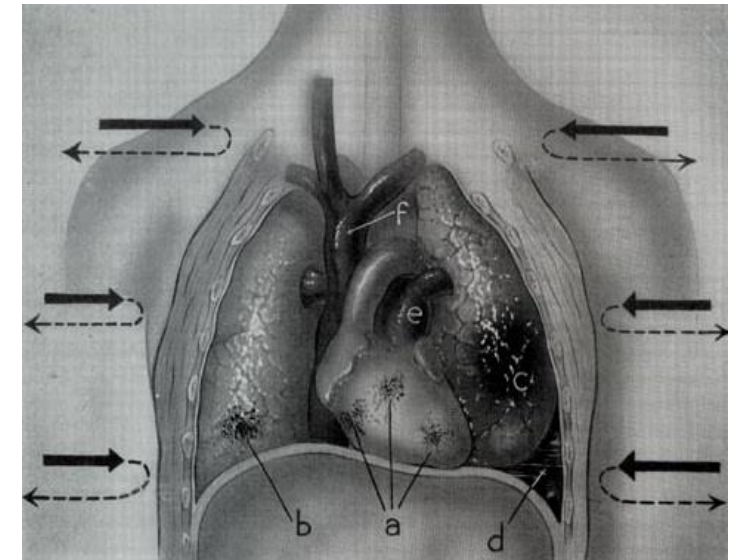
Blast Lung

- 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)

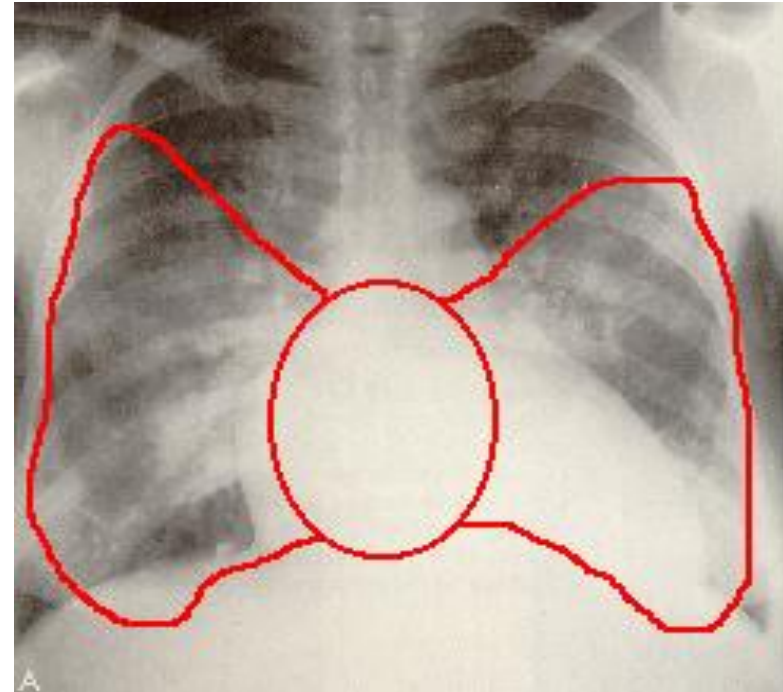


Blast Lung

- 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!**

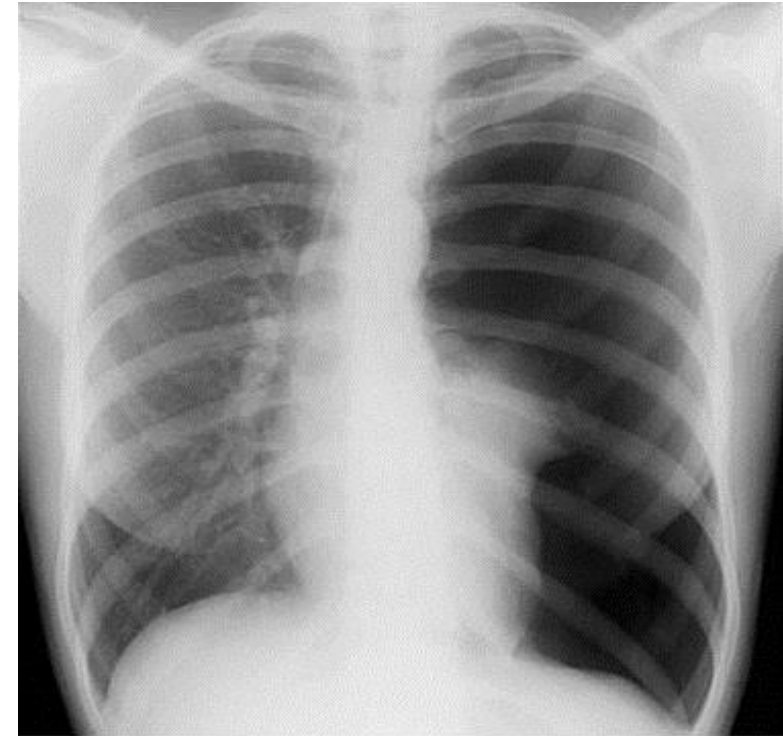
Blast Lung

- 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

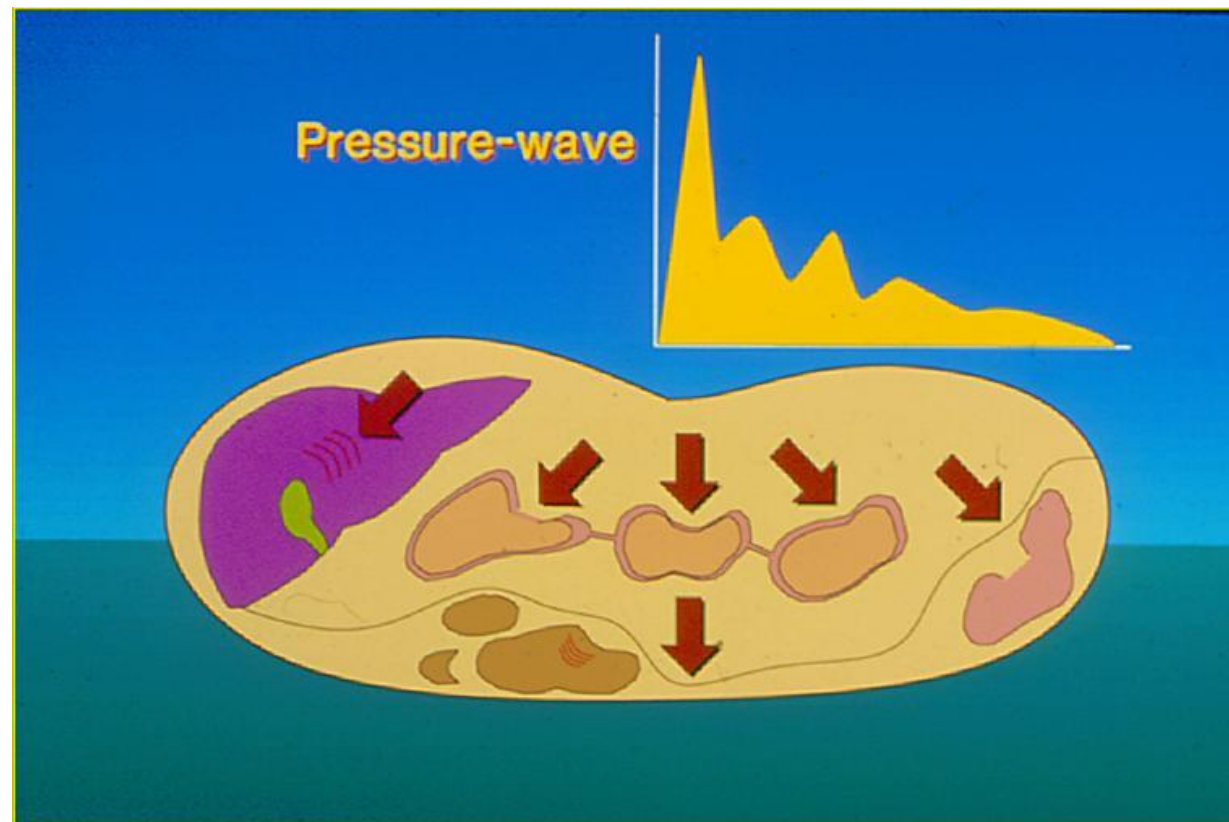


Blast Lung

- 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

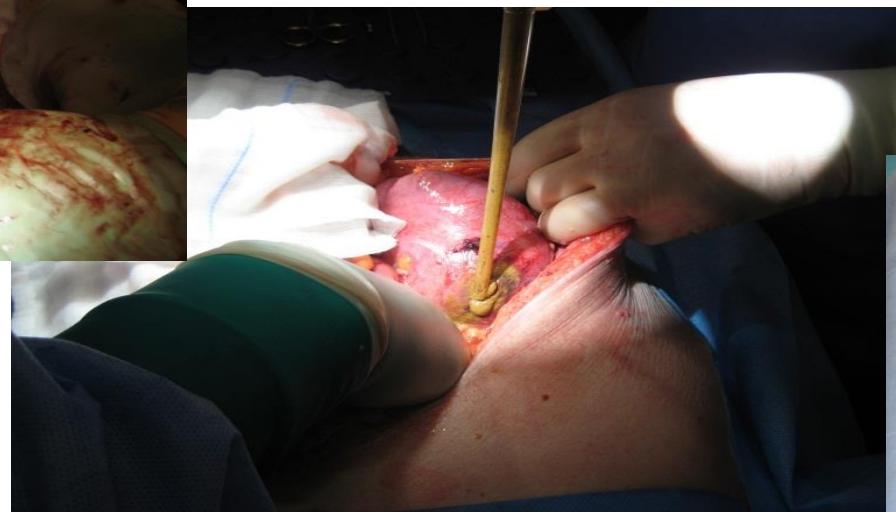
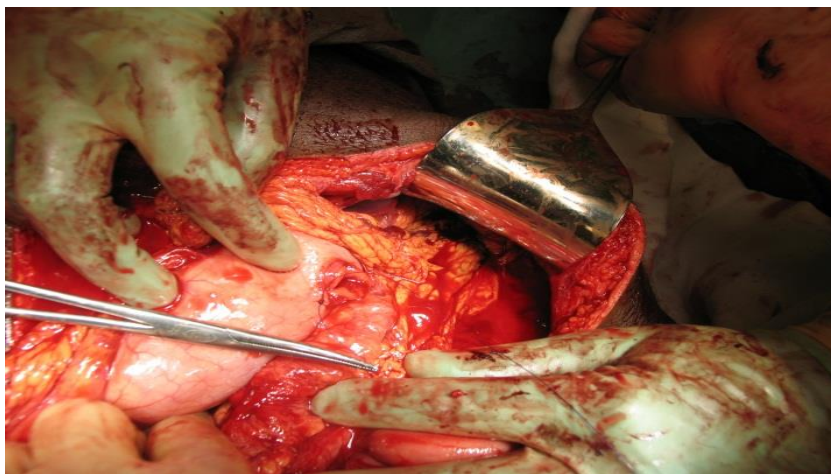
Blunt thoracic trauma: flail chest, pulmonary contusion and blast injury
Wanek S et al
Crit Care Clin 20(1): 171 – 181, 2004

Abdominal Injury



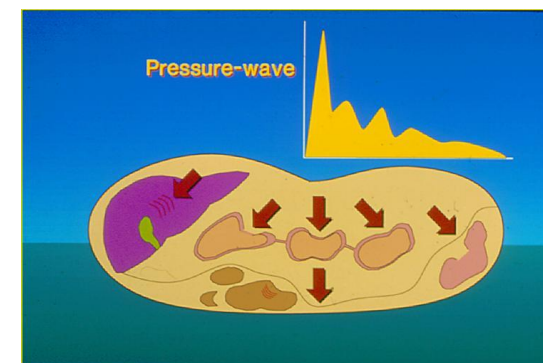
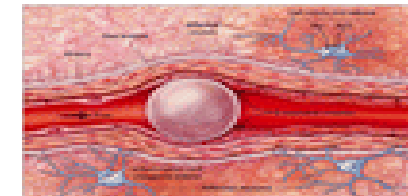
Abdominal Injury

- 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

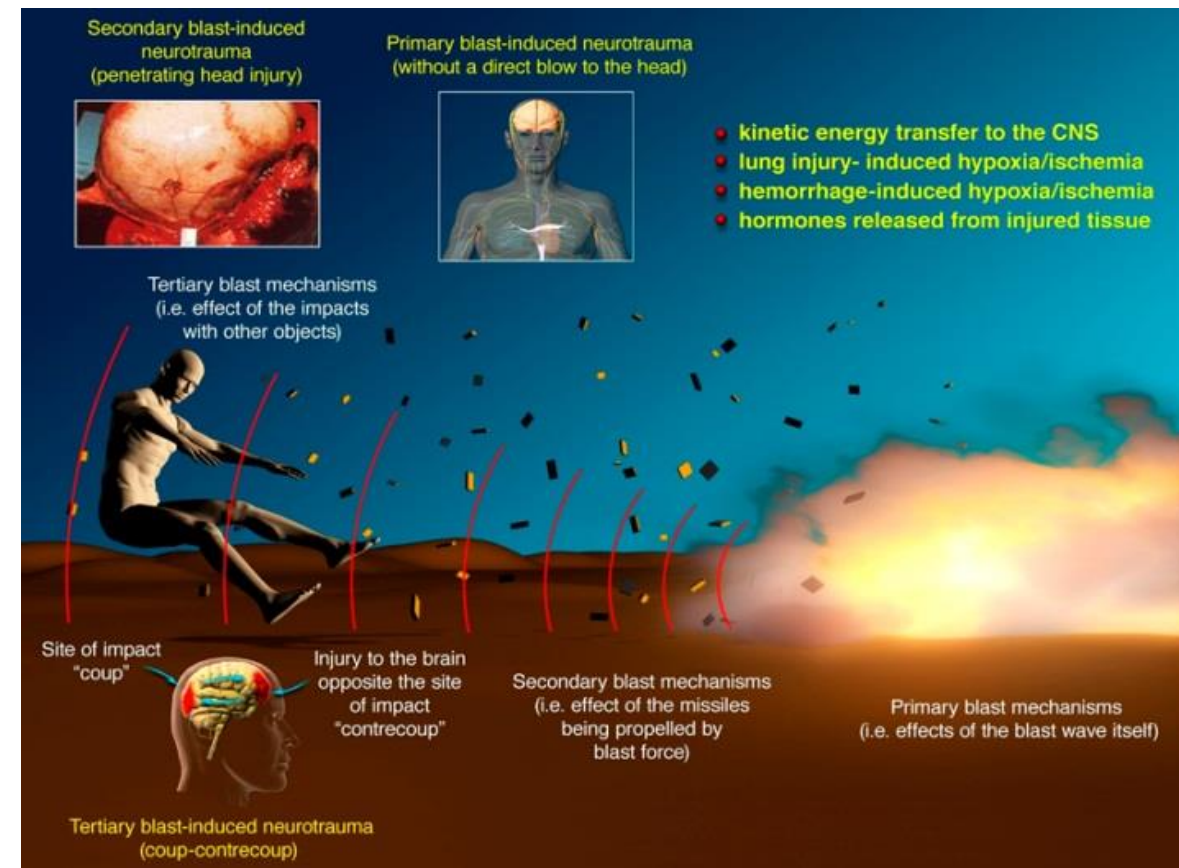


Eye Injury

- 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!**



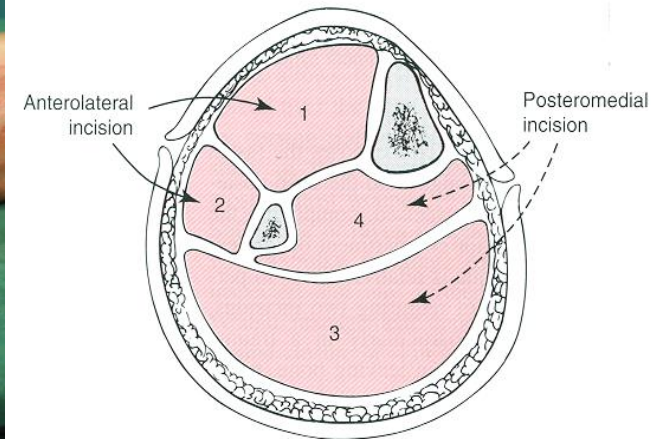
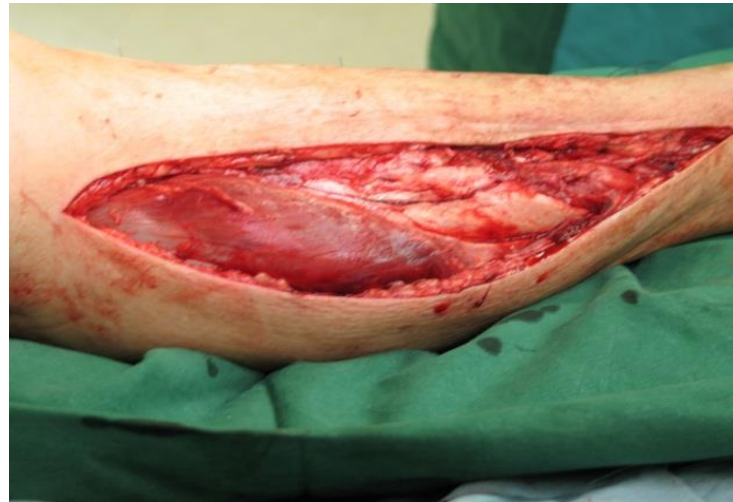
Crush Syndrome

- 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**

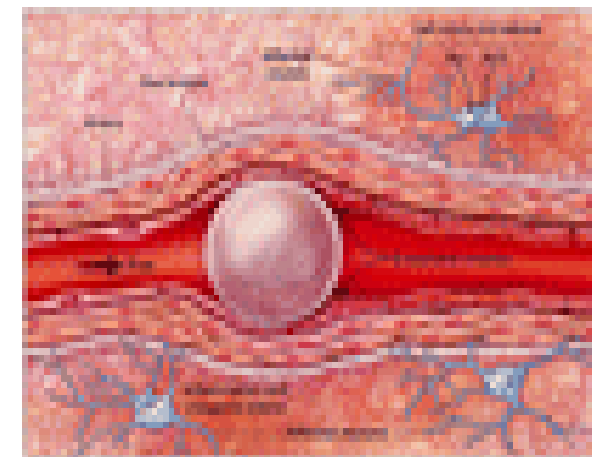
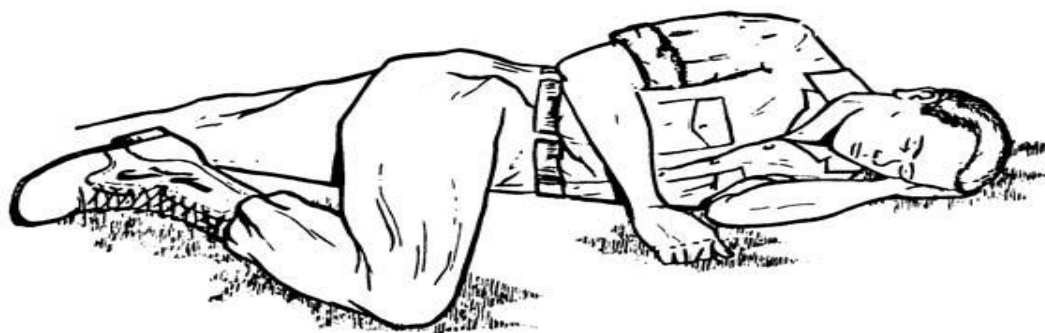
- Copious lavage and removal of particles and debris
- Rinse with 1% copper sulfate solution
 - Combines with phosphorous particles and impedes further combustion
- Cardiac monitor
 - Hypokalemia and hyperphosphatemia common
- Use moistened face masks to protect from phosphorous pentoxide gas exposure
- Avoid use of flammable anesthetic agents and excessive oxygen



Arterial Gas Embolism (AGE)

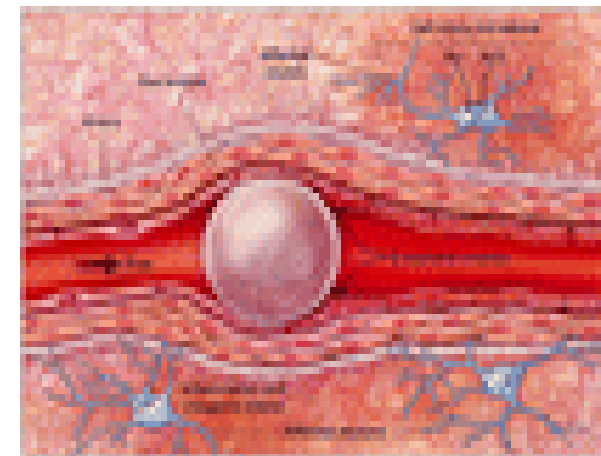
- Recompression with 100% oxygen
- Left lateral recumbent position

O₂



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

مستشفى المفرق
Mafraq Hospital

Thank you for listening



Don't dawdle, prompt action saves lives!

Fawzi al-Ayoubi 2017

