

Bomb and Blast Injuries

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- *“The blast wave is a shot without a bullet, a slash without a sword. It is present everywhere within its range. Blast would be as dreaded a weapon as chemical warfare, if its range, when explosives are used were not limited to small areas. However it would be premature to believe that this situation will always remain the same.”*

- **Theodor Benzinger 1950**

Global Disease

- Bomb and blast injuries are becoming more common in the civilian population
- Explosives are commonly used in terrorist events

Terrorism

- Aimed at innocent civilians
- Premeditated
- Political



Blast Injuries

- Result from:
 - Fireworks
 - Household explosions
 - Industrial accident
 - Motor vehicular accidents



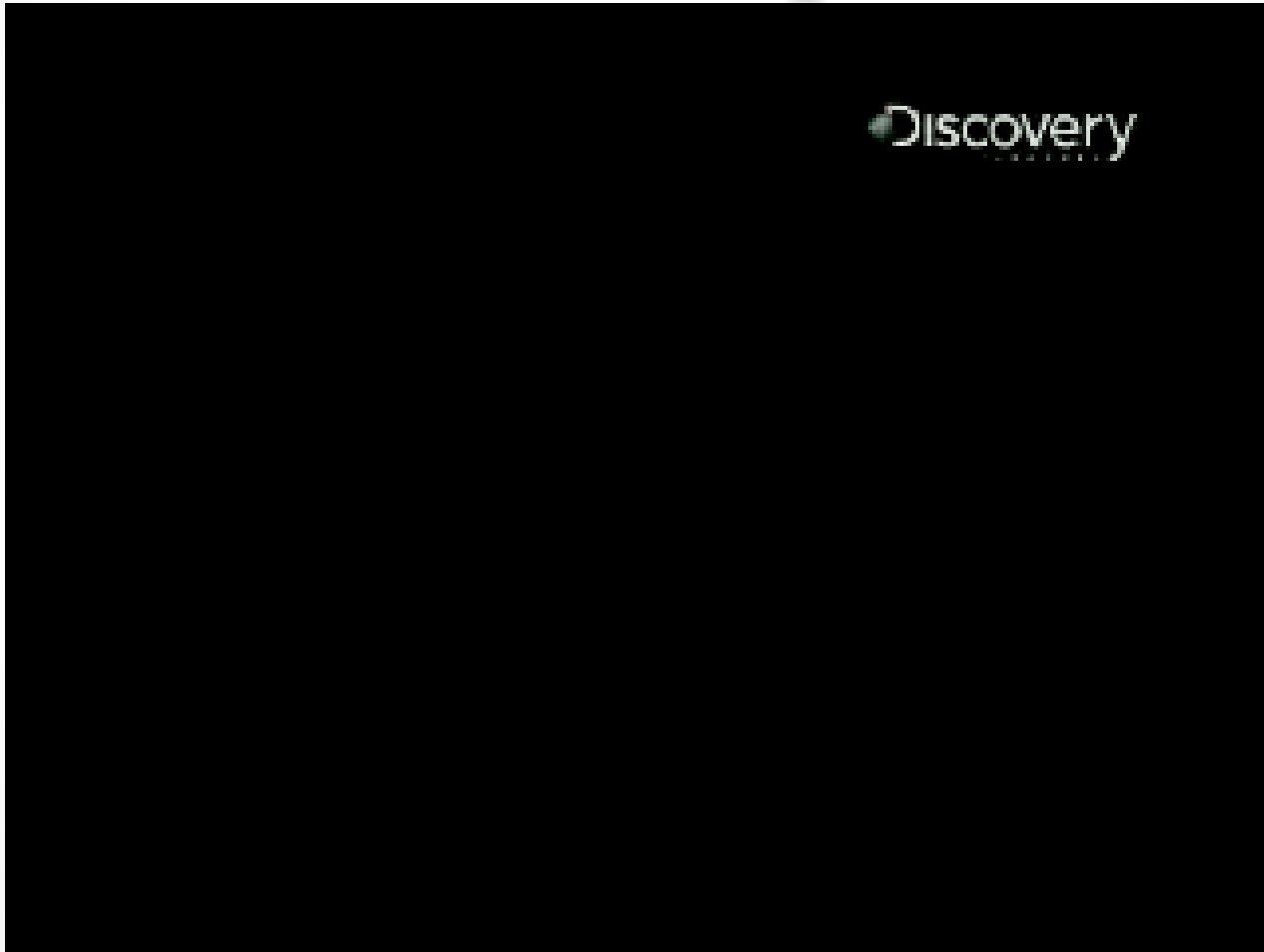
<http://www.industrytap.com/5-chemical-plant-explosions-and-what-caused-them/16655>

Terrorism Blast Injuries

- Result from:
 - Suicide bombers
 - Motor vehicle incidents
 - Airplanes...
 - Letter bombs
 - Suitcase bombs



Industrial Explosions



Blast Injuries

- Complex type of physical trauma resulting from direct or indirect exposure to an explosion.
- Blast injuries occur with the detonation of:
 - high-order explosives
 - deflagration of low order explosives

Explosions

- Single to multiple victims – mass casualties
- Explosions cause unique type of injuries
 - Lungs
 - Central Nervous System

Injury Patterns

- Product of:
 - Composition and amount of the materials involved
 - Surrounding environment
 - Delivery method (if a bomb)
 - Distance between the victim and the blast
 - Any intervening protective barriers or environmental hazards

Explosive Devices



<https://www.wibwnewsnow.com/possible-explosive-devices-found-junction-city-home/>

High-Order Explosive Devices

- Almost instantaneous **high pressure** rapidly expanding gases which compress the surrounding air resulting into **supersonic** over-pressurization shock or blast wave followed by negative pressure (suction)
- Detonation requires a chemical process that rapidly decomposes nitrogenous compound producing heat and gas as by-products
- Military
- Mass produced

High-Order Explosives

- TNT
- C-4
- Semtex
- Nitroglycerin
- Dynamite
- Ammonium Nitrate Fuel Oil (ANFO)

Low-Order Explosives

- Pipe bombs
- Gunpowder
- Most pure petroleum based bombs
 - Molotov cocktails
 - Aircraft improvised (guided missiles)

Blast Devices

- Characterized based on their source
- Explosive and Incendiary (fire) bombs
- Manufactured
 - Standard military issued mass produced weapons
- Improvised
 - Weapons produced in small quantities
 - Use of a device outside its intended purpose

Improvised Explosive Devices

- Improvised = homemade
- Made from explosives, commercial blasting supplies, or fertilizer and household ingredients
- Designed to cause injury, mayhem and death
- Often packed with metal objects such as nails or ball bearings
- Could contain toxic chemicals or radiological materials (dirty bomb)

Mechanism

- **Implosion**
- Shock wave travels through an organ containing pockets of air/gas
- Pockets of air/gas are compressed by the surrounding fluid
- The pockets of gas expand rapidly

Mechanism

- **Spalling**
- Occurs at the interface between media of different densities when the shock wave passes from a high density to a lower density substance

Mechanisms

- **Acceleration-deceleration**
- Blast wave accelerates tissues of different densities at different rates

Scene Hazards

- Secondary devices
- Shrapnel
- Building collapse
- Air-borne contaminants
- Contaminated patients
- Contaminated scene/environment
- Perpetrators
- Terrorist patients

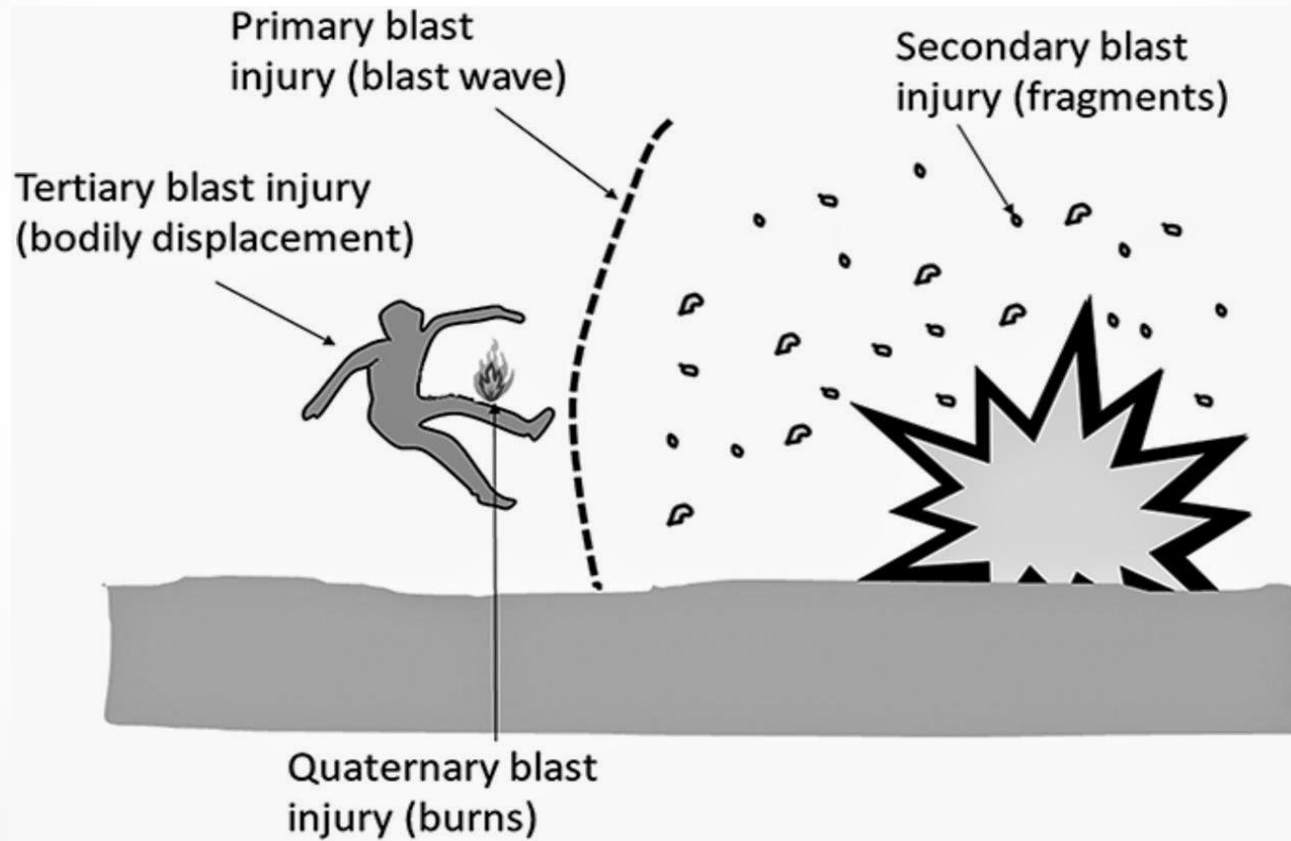
Scene Hazards

- Victims with no soft tissue injuries
- Vehicles coming out or leaving the scene
- People acting oddly
- Packages or containers at scene (out of place)
- Vehicles not damaged or out of place
- Structural damage
- Weather
- Possible places for secondary device
-

Blast Injuries

- Multi-system injuries
- Simultaneous life-threatening injuries
- Hidden patterns of injury
- Single or multiple victims
- Produce classic patterns from blunt and penetrating trauma
- Unique injury patterns
- Occult injury patterns

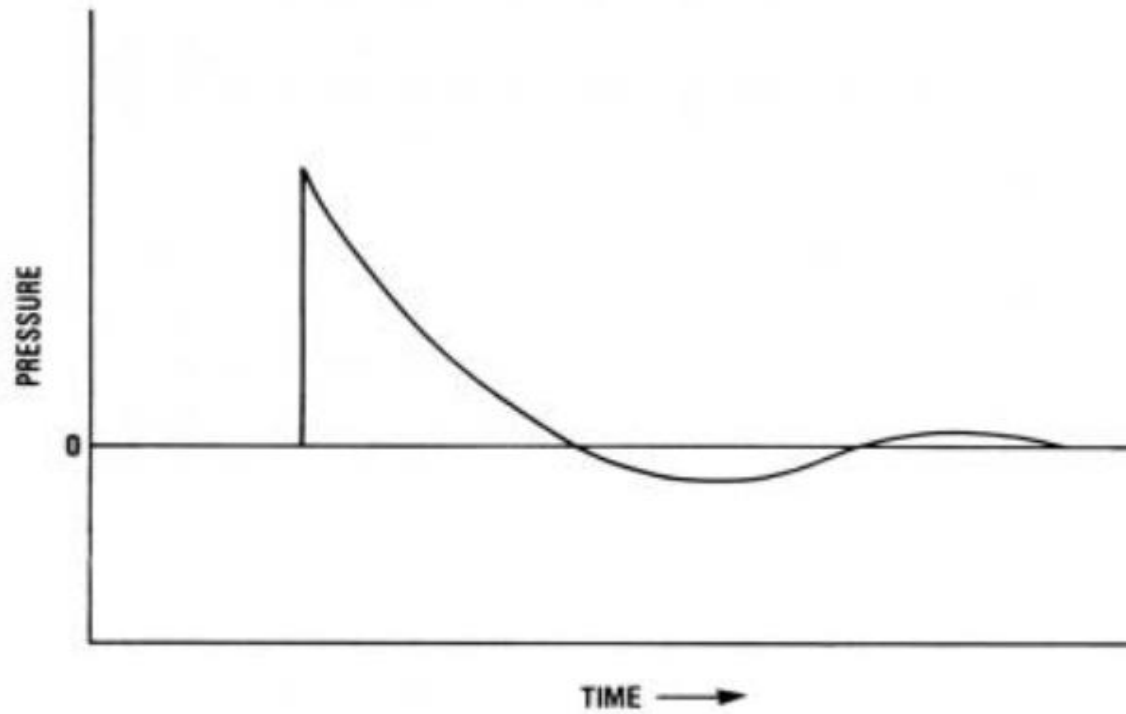
Blast Physics



Blast Injury Severity

- Nature of the device
 - Agent, amount
- Method of delivery
 - Incendiary, explosive
- The environment
 - Open vs closed
- Distance from the device
- Intervening protective barrier
- Environmental hazard

Blast Physics



Slow Motion Blast Wave



Open Air Explosion

- Air is a poor conductor of blast-wave energy

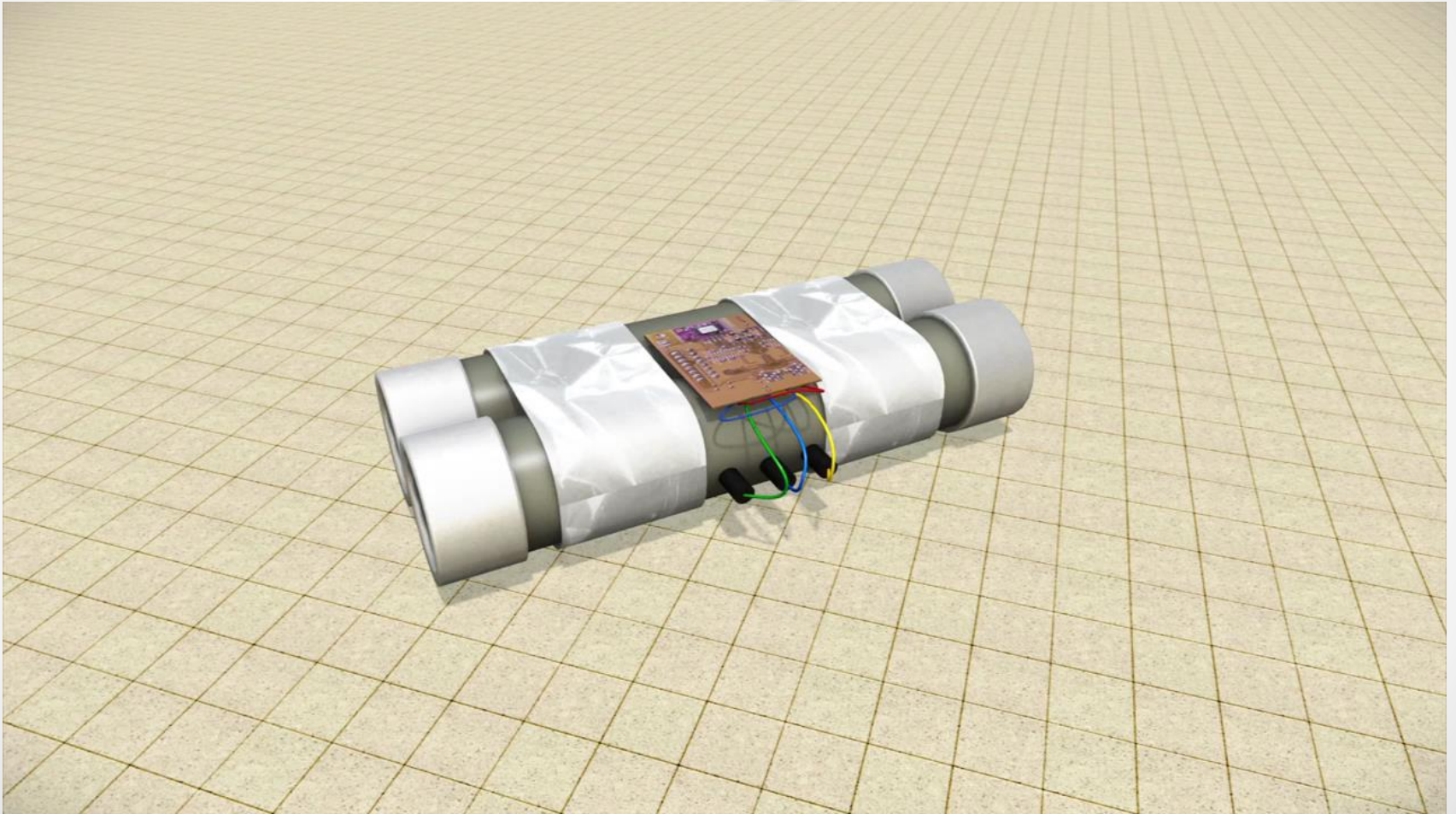
Closed Space Explosion

- Associated with greater morbidity and mortality
- Reflection of blast waves from walls and other surface creates more complex waves, and lasts longer



<http://nypost.com/2016/03/24/second-attacker-believed-to-be-involved-in-brussels-subway-bombing-reports/>

Why Bomb Blasts Are More Dangerous...



Primary Blast Injury

- Direct effect of the changes in the atmospheric pressure caused by the blast wave
- Occurs mostly in gas containing organs such as:
 - Lungs
 - Middle ear
 - bowel

Blast Lung

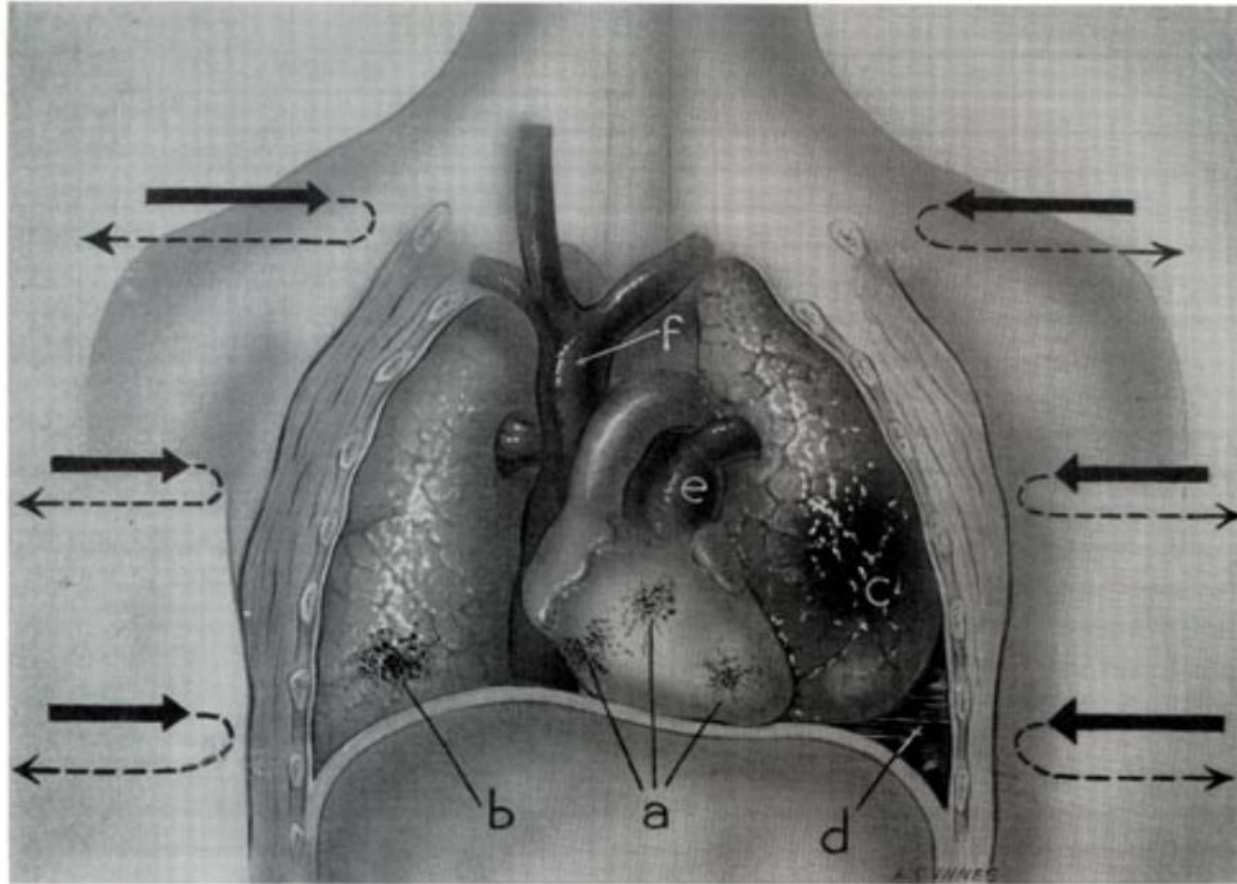
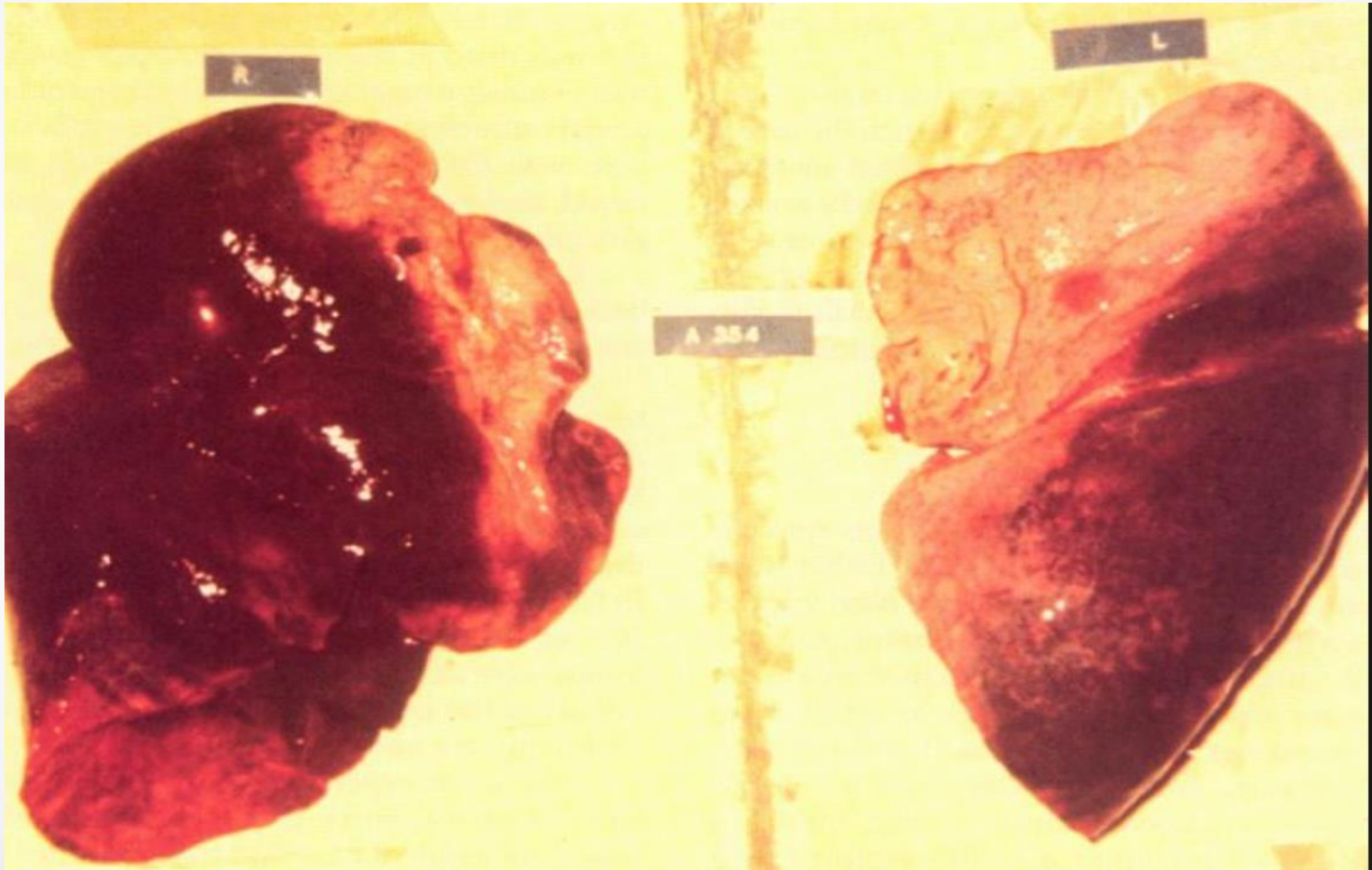


FIGURE 10.—Schematic showing of pathologic physiology of blast injury (wave of positive pressure shown by solid arrow, wave of negative pressure by dotted arrow) : Petechial hemorrhage, cardiac (a), petechial hemorrhage, pulmonary (b), gross pulmonary hemorrhage (c), pleural hemorrhage (d), engorged pulmonary artery (e), and engorged vena cava (f).

Blast Lung



https://commons.wikimedia.org/wiki/File:Blast_lung-bilateral_pulmonary_hemorrhage.JPG

Blast Lung

- Most common fatal primary blast injury
- Signs can be as late as 48 hours after initial injury
- Includes:
 - Pulmonary contusion
 - ARDS
 - Systemic air embolism
 - Brain
 - Spinal cord
 - Free radical associated injuries
 - Thrombosis
 - DIC

Blast Lung

- Wheezing can be from:
 - Pulmonary contusion
 - Inhalation of gases
 - Inhalation of dusts
 - Pulmonary edema
 - Adult Respiratory Distress Syndrome
- Apnea
- Cough
- Hemoptysis
- May need prophylactic chest tube if blast lung is suspected and need to fly patient

Blast Lung

- Clinical triad
 - Apnea
 - Bradycardia
 - Hypotension
- Suspect if:
 - Dyspnea
 - Cough
 - Hemoptysis
 - Chest pain

Blast Thorax

- Decreased heart rate
- Hypotension
- Normal reflex to increase systemic vascular resistance does not occur
- This is not observed anywhere else in medicine – PBI that can cause death in the absence of any demonstrable physical injury
- Pericardial tamponade

Blast Ear

- Acoustic Barotrauma
- Tympanic rupture (most common)
 - As low as 5 psi can rupture the TM
 - Overpressure of 15 psi will cause TM rupture
- Hemotympanum without perforation
- Ossicle fracture or dislocation
- May have other associated injuries
- May not be present if wearing some type of hearing protection

Blast Ear

- Suspect if:
 - Hearing loss
 - Tinnitus
 - Otalgia
 - Vertigo
 - Bleeding from external canal

Blast Ear



Figure. Otoscopy shows the injury to the right tympanic membrane.

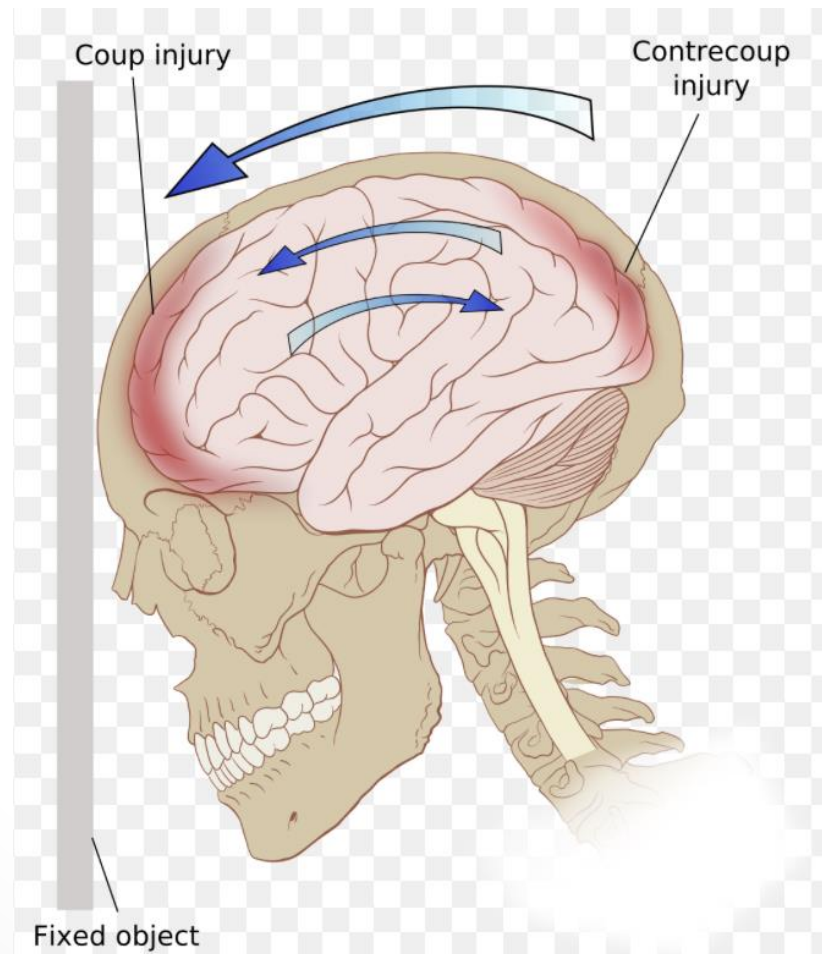
Abdominal Injuries

- Gas-containing portions are most vulnerable
- Bowel perforation
- Hemorrhage
- Shear injuries
- Look for:
 - Abdominal pain, tenderness, rebound guarding, absent bowel sounds
 - Nausea, vomiting
 - Rectal/testicular pain
 - Tenesmus

Traumatic Brain Injury

- Concussion
- Mild traumatic brain injury
- Consider:
- Proximity to explosion
- Headache
- Fatigue
- TBI can mimic Post-traumatic stress disorder

Traumatic Brain Injury



Traumatic Brain Injury

- Physical Signs
 - Headaches
 - Dizziness
 - Nausea, vomiting
 - Blurred vision
 - Insomnia
 - Fatigue
 - Unsteady gait

Traumatic Brain Injury

- Behavioral Signs
- Irritability
- Depression
- Anxiety
- Problems with emotional control
- Social issues
- Memory issues
- Concentration issues

Secondary Blast Injury

- Caused by flying objects that strike people:
- Shrapnel
- Debris from the blast
- Majority of casualties in many explosions

Oklahoma Bombing 1995

- Claimed 168 lives
- 19 children under the age of 6
- Injured > 680 people
- Blast destroyed / damaged 324 buildings within a 16 block radius
- Burned 86 cars
- Shattered glass in 258 nearby buildings



Oklahoma Bombing 1995

- 20 infants and children were seated by the window of the second floor day care center
- 16 from the day care died
- Injury patterns:
- Skull fracture
- Cerebral evisceration
- Abdominal or thoracic injuries
- Amputations
- Arm fractures
- Leg fracture
- Burns
- Extensive cutaneous contusions, evulsions, lacerations



Tertiary Blast Injury

- Injuries from:
- High-energy explosions
- Or person was very close to the explosion source
- Collapsing buildings
 - Crush injuries
 - Projectiles
- Body being displaced by the explosion
- Internal body organs being displaced by the expanding gases

Additional CNS Injuries

- Concussion
- Closed or open brain injury

Additional GI Injuries

- Bowel perforation
- Ruptured liver
- Ruptured spleen

Additional Renal Injuries

- Renal contusion, laceration
- Acute renal failure:
- Rhabdomyolysis
 - Hypotension
 - Hypovolemia

Additional Extremity Injuries

- Traumatic amputation
- Fractures
- Burns
- Lacerations
- Air embolism
- Acute arterial occlusion
- Compartment syndrome

Traumatic Amputation



Additional: Ocular Injury

- 10% of blast survivors have significant eye injuries
- Perforated globe
- Foreign body
- Air embolism
- Subconjunctival hemorrhage
- Lid lacerations



Ruptured globe. Courtesy of the American Academy of Ophthalmology

Quaternary Blast Injury

- All other injuries caused by explosions
- Burns
 - Chemical
 - Thermal
 - Radiation
- Inhalation:
 - Dust
 - Smoke

Thermal Injuries

- Blast wind: forced superheated air flow generated by the explosion
- Flash burns
- Varying degrees and depths of burns
- Necessitates adequate fluid resuscitation and wound treatment

Air China Explosion



Inhaled Toxins

- Carbon Monoxide
- Cyanide
- Methemoglobinemia

White Phosphorus Burns

- Moistened face mask and good ventilation to protect from pulmonary effects of phosphorous pentoxide gas
- Remove identifiable particles
 - Place in water to prevent further combustion
- Initial management includes copious lavage of the area
- Cover area with saline-soaked gauze
- May lead to hypokalemia and hyperphosphatemia:
 - EKG changes
 - Cardiac arrhythmia
 - death



Unique to Blast

PRIMARY

- Blast lung
- Eardrum rupture and middle ear
- Abdominal hemorrhage and perforation
- Eye rupture
- Non-impact, blast-induced mTBI?

SECONDARY

- Penetrating ballistic (fragmentation) or blunt injuries
- Eye penetration

TERTIARY

- Fracture and traumatic amputation
- Closed and open brain injury
- Blunt injuries
- Crush injuries

QUATERNARY

- Burns
- Injury or incapacitation from inhaled toxic fire gases

QUINARY

- Illnesses, injuries, or diseases caused by chemical, biological, or radiological substances (e.g., "dirty bombs")

***PSYCHOLOGICAL TRAUMA (including PTSD)**

- Added based on latest research suggesting a high risk of developing PTSD following a concussion

Emergency Medical Services

- Scene safety
- Personnel Protect Equipment
- Determine nature and size of explosion
- Time of occurrence
- Proximity of victims to explosion
- Victim count
- Victim displacement
- Presence of
 - Fire
 - Smoke
 - Dust
 - Chemical contamination
 - Radioactive contamination

Emergency Medical Services

- Entrapment
- Activating disaster response
- Need for HazMat
- Screening for Radioactive contamination
- Early use of tourniquets for significant extremity trauma and exsanguination for bleeding control

THANK YOU



References

- Bowen TE, Bellamy RF eds 1988. Blast injuries. Idealized graph of a blast pressure wave over time. Emergency War Surgery. Washington, DC: United States Government Printing Office, 1988.
- Gadre, Arun K. "Blast injury to the tympanic membrane." *Ear, Nose and Throat Journal*, Nov. 2005, p. 686. Academic OneFile,
- Horrocks, CL **Blast Injuries: Biophysics, Pathophysiology and Management Principles** *J R Army Med Corps* 2001; **147**: 28 -40
- <https://www.cdc.gov/mas/trauma/preparedness/primer.pdf>
- <http://emedicine.medscape.com/article/822587-overview>
- <http://history.amedd.army.mil/booksdocs/wwii/thoracicsurgeryvoll/chapter1.htm>
 - Brewer, LA, et all
- Ryan's Ballistic Trauma: A Practical Guide. Eds. Brooks A.J., Clasper J., Midwinter M., Hodgetts T. J., Mahoney P. F. Springer; 3rd Ed.(2011) p.52 [ISBN 1848821239](https://www.amazon.com/dp/1848821239)
- Quintana, DA et al 1997. The spectrum of pediatric injuries after a bomb blast. [**J Pediatr Surg.** 1997; 32\(2\):307-10; discussion 310-1](#) (ISSN: 0022-3468)