BOMB, BLAST & CRUSH INJURIES

THESE TYPES OF INJURIES ARE AMONG THE FEW INSTANTANEOUS TRAUMATIC EVENTS THAT CAN PRODUCE MASSIVE NUMBERS OF CASUALTIES REQUIRING IMMEDIATE MEDICAL ATTENTION.

THE MAJORITY OF INJURIES SUFFERED BY THE IMMEDIATE SURVIVORS OF BOMBINGS ARE NOT LIFE-THREATENING.

HOWEVER, BOMBING CASUALTIES HAD HIGHER INJURY SEVERITY SCORES, INCREASED IMMEDIATE MORTALITY, GREATER IN-HOSPITAL MORTALITY RATE, MORE FREQUENT NEED FOR SURGERY, LONGER HOSPITAL STAYS AND GREATER USE OF CRITICAL CARE COMPARED TO OTHER FORMS OF TRAUMA

PATHOPHYSIOLOGY:

- Explosions occur when is energy is transformed extremely quickly from one form to another (chemical potential energy to heat/kinetic energy)
- The detonation generates a BLAST WAVE that spreads out from a point source and consists of a SHOCK WAVE (of high pressure) followed closely by a BLAST WIND (or air mass in motion)

There are FOUR MAIN TYPES OF BLAST EFFECTS:

- PRIMARY INJURY
  - Direct effect of blast overpressure on tissue
    - affects air filled tissue (lungs, ears, GIT) via “spalling”, (which causes explosion of tissue)
    - shearing due to differential inertia (pulmonary vessels and air spaces --> ruptured bronchial pedicles and vasculature)
    - implosion of flexible air spaces (cases rebound to greater than original size)
- SECONDARY INJURY
  - Due to collateral damage from flying objects and shrapnel

Secondary blast injury to chest and abdomen, imaging is often needed to assess internal injuries

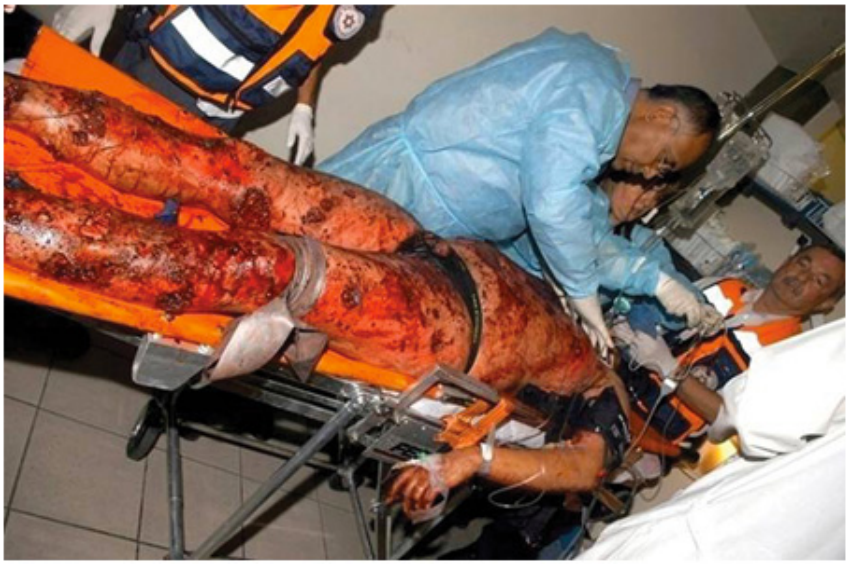
- TERTIARY INJURY
  - Results from the victim being propelled through the air
- QUATERNARY INJURY
  - Burns, smoke inhalation or chemical agent release

PREDICTING EFFECTS OF A BOMB ARE DIFFICULT, BUT SOME PRINCIPLES ARE OUTLINED BELOW:

- DISTANCE OF VICTIM FROM EXPLOSION
  - Intensity declines with CUBED ROOT of distance, hence proximity of the victim to the explosion is an important factor in a primary blast injury
- ENCLOSED VERSUS OPEN SPACE
  - Closed space have more severe injuries and higher mortality
- SURROUNDING ENVIRONMENT
  - Blast waves are reflected by solid surfaces, hence greater injuries if standing against a wall
- QUANTITY OF EXPLOSIVE
- TYPE OF EXPLOSIVE
- EMBEDDED SHRAPNEL
  - Maximise secondary injury

CLINICAL FEATURES:

- Nature of injury may produce many external signs, making detection of important internal injuries challenging



CARDIOPULMONARY SYSTEM:

- THE LUNG IS VERY SUSCEPTIBLE TO PRIMARY BLAST INJURY
- Pulmonary barotrauma is the MOST COMMON FATAL PRIMARY BLAST INJURY, especially in those close to the blast centre

Severe lung injury. Came in conscious and stable.

- Pressure differentials across the alveolar-capillary interface can cause disruption, haemorrhage, pulmonary contusion, pneumothorax, haemothorax, pneumomediastinum and subcutaneous emphysema
    - Air and fat embolism have also been reported
- In general, management of blast lung injury is similar to caring fro pulmonary contusion and ARDS except that early symptoms MAY APPEAR BENIGN
    - Monitor RR and oximetry
    - Ensure tissue perfusion without volume overload
    - Decision to institute mechanical ventilation should be made carefully due to limited critical care resources and also exposes the patient to further complications of barotrauma
    - TIDAL VOLUME KEPT TO 6-7 ml/kg of ideal body weight with aims to limit peak inspiratory pressure and to minimise ventilator-induced lung barotrauma
        - PERMISSIVE HYPERCAPNIA
        - Consider ECMO early
- Asymptomatic patients at 4-6 hours with normal CXR CAN BE DISCHARGED

EARS:

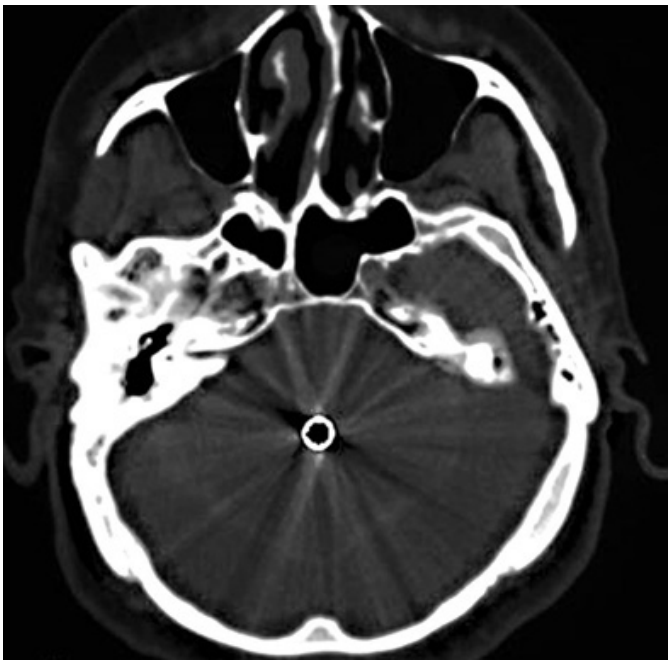
- The tympanic membrane ruptures at 1-8 PSI
- Dislodgement of ossicles may occurs
- If TM ruptured, but no other injuries --> CXR should be performed
    - Conversely, intact TMs do not imply absence of serious injuries.

ABDOMEN:

- Injuries from explosions may be occult
- Reported injury rates are low, but missed injuries carry significant morbidity due to delayed intestinal perforation and necrosis
    - Prolonged observation if suspicious
- Air is a poor conductor of blast wave energy, thus if patients were subjected to enough energy to damage abdominal organs, then they were probably close to the device and have other injuries as well

BRAIN INJURY:

- Incidence of diffuse injuries, with or without penetrating brain injury is increasing
- Shrapnel are low velocity missiles that produce small entry wounds and thus may be missed under the hair and evidence of brain injury may be masked by sedative agents used to treat other life-threatening injuries
- EARLY IMAGING is KEY



CT of bomb-blast victim who walked into ED and then deteriorated, requiring emergent neurosurgical intervention to remove shrapnel.

VASCULAR INJURY:

- Small entry wounds from shrapnel may mask severe vascular injuries
- Compartment syndrome may occur
    - Clinical observation for delayed presentation is important
- BLEEDING FROM EXTERNAL WOUNDS
    - Very commonly encountered & may be sufficient to cause hypovolaemic shock
    - Quick control with direct pressure or tourniquets.
    - Angiographic vascular occlusion is attractive if time/staff are available

OCULAR INJURIES:

- Common. ~8% incidence.
- Lacerations to lid or brow. Open globe, orbital fractures, retinal detachment or retained foreign body
- Hence eye exam mandated in all moderately severe bomb victims

IMAGING:

- Should be used *judiciously* in mass casualty event
- FAST should be used liberally
- CT use is controlled by disaster commander

TREATMENT:

- When blast injuries occur, they tend to be unexpected, occur outside of regular working hours and produce larger numbers of simultaneously arriving casualties
- The nature and location of the blast (open vs closed space, structural collapse, associated fire/smoke, toxic agent release) all should be discerned ASAP as it helps form clinical decisions

PATIENTS TRIAGED AS BELOW

Table 8-1 Criteria for the Triage in Bomb Injuries

Severely Injured	Lightly Injured
Airway compromise	Minor wounds
Breathing difficulty	Burns, degree I–II
Hemodynamic instability	Isolated trauma to a limb
Altered level of consciousness	Anxiety states
Vascular trauma	Most walking patients
Extensive second- to third-degree burns	

BASIC EMST/ATLS PROTOCOLS OF PRIMARY AND SECONDARY SURVEY SHOULD BE FOLLOWED

- Administer IV fluids/blood judiciously
- Lab tests, imaging rationed by disaster commander
- COPIOUS IRRIGATION AND DISINFECTION OF WOUNDS should be performed urgently, but definitive debridement and close may wait for hours

- IV antibiotics:
    - If wound severely soiled, penetrating chest/abdo wounds, open fractures or those with diabetes or are immunocompromised
- All patients exposed to open-space explosions with no apparent injuries who remain well after 4-6 hours can be discharged.
- Those who are exposed to close-spaced blast with/without TM injury *should have a CXR*
- All those with significant burns, suspected air embolism, radiation/chemical contamination or abnormal vital signs and visceral injuries should be admitted.
- Secondary assessment prior to discharge
    - Pulmonary contusion and intestinal haematoma may take 12-48 hours to manifest, so instruct to return if they become SOB or develop abdominal pain or vomiting
- PREGNANT PATIENTS:
    - Direct injury to the foetus is uncommon, but injuries to the placenta are more common
    - CTG monitoring for those women in 2-3rd trimester who are exposed to blast injury
    - Administer anti-D to those who Rh-negative
- CHILDREN:
    - Suffer significant tertiary blast injury because their lighter bodies are more easily hurled by the blast wind
- BEWARE STAFF SAFETY:
    - Unexploded bombs, transmissible disease risks, contamination by chemical, radiation, biologic hazards.

CRUSH INJURY AND THE CRUSH SYNDROME:

- CRUSH INJURY occurs when a body part is subjected to a high degree of force or pressure, usually after being squeezed between two heavy or immobile objects
- Crush injury that produces ongoing ischaemia of a fascial muscle compartment is termed “COMPARTMENT SYNDROME”
    - Defined as increased pressure within a confined space that leads to microvascular compromise and ultimately to cell death as a result of oxygen starvation
- CRUSH SYNDROME
    - The systemic manifestation of muscle cell damage resulting from pressure or crushing with/without subsequent compartment syndrome
        - Most commonly seen in extremities
        - High incidence of associated fracture, degloving and lacerations

PATHOPHYSIOLOGY:

- Most types of muscle injury result in extracellular calcium
- With increasing cellular injury and death --> potassium, phosphate, myoglobin, creatine kinase and urate --> into bloodstream.
- Circulating myoglobin injures the kidney
- Membrane damage leads to vascular volume loss and hypovolaemia
- *HYPERKALAEMIA and hypocalcaemia* may cause arrhythmia and cardiac arrest
    - Metabolic acidosis due to hypovolaemia and toxins aggravates arrhythmogenecity
- *Renal failure is the most serious complications* of crush syndrome
    - Multifactorial due to systemic hypoperfusion, nephrotoxicity due to myoglobin/urate and phosphate precipitation in distal tubules
- ***REPERFUSION SYNDROME***
    - Paradoxical phenomenon of exacerbation of cellular dysfunction after restoration of blood flow to previously ischaemic tissues
- Pressures ≥30mmHg produce muscle ischaemia with irreversible muscle and nerve damage occurring after 4-6 hours

CLINICAL FEATURES:

- CRUSH INJURY
    - Obvious signs usually apparent with associated lacerations, degloving, pain and ischaemia

- COMPARTMENT SYNDROME = FIVE ‘P’s:
    - PAIN
        - Most common, diffuse/intense, exacerbated with movement, touch or pressure and is out of proportion to physical exam
    - PARAESTHESIA or anaesthesia
    - PASSIVE STRETCH
        - Severe pain when muscles in affected compartment are stretched
    - PRESSURE = increases above 30 mmHg
    - PULSELESSNESS = least reliable and occurs late

- CRUSH SYNDROME
    - Due to manifestations of muscle toxin release and hypovolaemia.
    - Hypovolaemic shock may occur and be aggravated by hyperkalaemic, hypocalcaemic or acidaemic cardiotoxicity.
    - Renal failure may ensue quickly and is the primary source of delayed death

LABORATORY EVALUATION:

- Serum CK may not necessarily predict disease severity or risk of renal failure, but they are a useful initial triage and subsequent follow up.
- Close attention should be paid to potassium, calcium, phosphate, pH, creatinine, Hb, urine pH and coagulation profile

TREATMENT:

- BEFORE/DURING EXTRICATION
    - Two large bore IVC with saline bolus and if entrapment is prolonged, then bicarbonate should be considered (one ampoule per hour).
    - Analgesia

- AFTER EXTRICATION (or after fasciotomy)
    - Serum potassium should be monitored serially and admitted to ICU.
    - Maintain UO at 200-300ml/hour.
    - Urinary alkalinisation to pH >6 with addition of bicarbonate.
    - Emergent haemodialysis may be needed for patients with anuria, hyperkalaemia or volume overload.

- FASCIOTOMY
    - The Israeli experience has demonstrated better results by NOT ROUTINELY PERFORMING DELAYED FASCIOTOMIES
    - Indicated if victim can be extricated and receive definitive medical care within 6 hours but <12 hours.
    - If paralysis is noted, the patient may not necessarily undergo fasciotomy.

- HYPERBARIC OXYGEN THERAPY
    - Gives sufficient oxygen dissolved in plasma to keep tissues alive despite adequate Hb-bound oxygen.
    - Oedema reduction secondary to vasoconstriction is another effect of oxygenation, which reduces blood flow by 20% but that blood that is delivered is oxygen rich.