# Blast Injuries: Terrorism Implications for Children during Peacetime/Wartime/Global Conflicts

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## True or False?

- Most terrorist attacks involve explosive devices?
- Bombings are mainly directed at the government?
- Most of the mass-casualty terrorist events in the United States have involved the use of unconventional explosives?

## True or False?

- Factors affecting the type and severity of blast injury include all of the following:
  - Whether structural damage with collapse occurred
  - Whether blast occurred in open air or in a building
  - Proximity to the blast epicenter

## True or False?

- Terrorist do not target really target children?
- Traumatic Brain Injury is associated with only primary blast injuries?

## Objectives

- Explain the concept of blast physics
- Identify 2 categories of explosives
- Enumerate the 4 types of blast injury and its relation to traumatic brain injury
- Identify clinical features of traumatic brain injury in explosions

## Objectives

- Identify factors affecting blast type and severity
- Describe unique vulnerabilities in children that place them at risk during a blast event

# Historical Context: Past & Present, Where are we?

- US 1983 – 2002 (*J Trauma* 2005 Dec; 59(6);1436-40)
  - >36,000 bombing incidents;
  - >5,900 injured; 699 deaths
- US hospital surge capacity not adequate enough to deal with the "predictable surprise"
  - *US House of Representatives Committee on Government Oversight and Reform 2008*

*We have not reached parity with them. We have the right to kill four million Americans — two million of them children —and to exile twice as many and wound and cripple hundreds of thousands. Furthermore, it is our right to fight them with chemical and biological weapons, so as to afflict them with the fatal maladies that have afflicted [us] because of the [Americans'] chemical and biological weapons."*

--The Middle East Media Research Institute: Special Dispatch Series—No. 388.

## Children targeted in Spanish car bomb blast

## Children targeted in Oklahoma car bomb blast

## Overview

- Terrorists have targeted areas with a large population of children in order to cause more harm and incite emotional upheaval
- Medical care for children in general, and during disasters *differ* from care for adults

## The Threat

- Game has changed; it's REAL!
- Unconventional Weapons
  - WMD
  - CBRN
- High Explosives

## Background

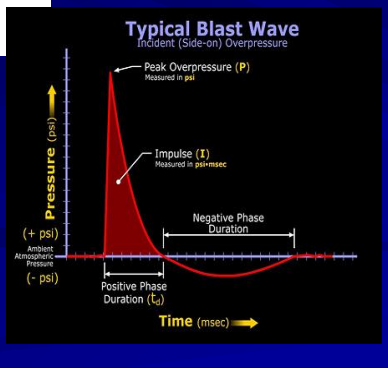
- Domestic and International bombing experience has augmented awareness level of non-military health professionals
- Readily available internet information on how to build a bomb
- Raw materials are easily obtained

## Background

- Most terrorist attacks involve explosive devices
- Increasing # of bombings directed at civilians
- Most mass-casualty terrorist events in the US have involved conventional explosives

# Blast Physics

Solid/Liquid to Gaseous state




# Clinical Implications

- Open vs Closed space
  - Walls and ceilings, especially enclosed areas (e.g. bus), amplify the “over-pressure effects” as they reflect the blast waves.
  - Anticipate the number, type, and severity of injuries observed
- Orientation of the victim to the blast
  - Blast effect is indirectly related to the distance between the victim and the explosion site—the closer to the explosion, the greater the extent of injury
- Other factors
  - Body mass of the victim (grave implications for young children)
  - Shielding present between the victim and the blast

# Explosive Types

- High-order (HE)
  - C4
  - TNT
  - NTG
  - ANFO
- Low-order (LE)
  - Gunpowder/black powder

CDC TIIDE project: Blast Injuries

# Explosives: Characteristics

- Designed to detonate in crowded areas and release metallic fragments (shrapnel), optimizing fatality and injury severity
- Sub-types
  - suicide bombs
  - package bombs
  - vehicle bombs

## Suicide Bombs

- Unique
- Intentional death of the bomber
- More likely to be successful (evade detection)
- Difficult to interdict
- Risk of transmission of blood-borne infections (e.g. hepatitis B or C) in patient survivors (few anecdotal cases)

## Car Bombs

- Heavy explosive material w/ big blasts
- Infrastructure damage and collapse
- Hundreds of victims will result
- Many will require extrication/technical rescue and treatment for crush injury or crush syndrome
- Most likely to be incendiary, producing burn injuries in patients as a result of secondary fires

## Crush syndrome

- A severe shock-like condition that follows release of a limb or other large body part after a prolonged period of compression, characterized by swelling, blood in the urine, and kidney failure

## Package Bombs

- Smaller in size
- Easy to delivery
- Confined places (e.g. bus, section of a building)
  - Closed space results in magnifying the resultant injury

## Types of Blast Injury (Blast Effect)

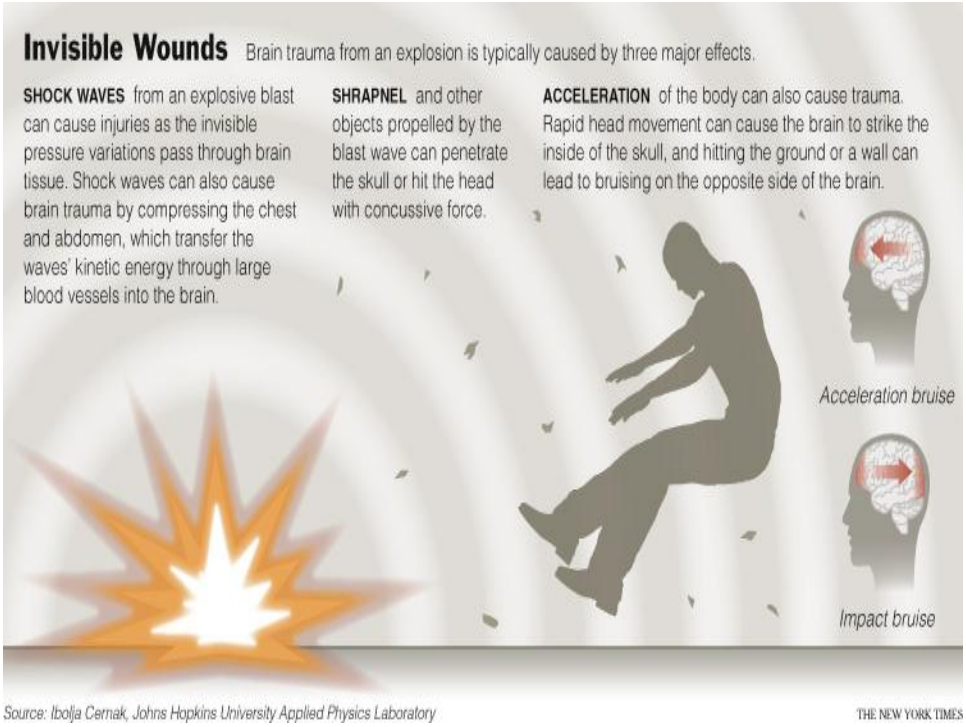
- Primary
- Secondary
- Tertiary
- Quaternary

## Primary Blast Injury

- Result of over-pressurization wave (blast wave)
- Air-filled organs injured damaged from high external overpressure
- Effect of the blast wave at the air-body interface (e.g. ear, lung, and intestines)

# Types of Primary Blast Injury

- Brain Blast Injury (Traumatic Brain Injury)
- Auditory Blast Injury
- Lung Blast Injury
- Abdominal Blast Injury



## Brain Blast Injury

- Controversial; evident in animal models
- ? Link to Post-traumatic stress disorder
- Severe head trauma is most common cause of death in terrorist bombings
- ~50% of critical injuries in terrorist bombings
- Increasing incidence of survival from TBI among US troops in Iraq and Afghanistan

## Brain Blast Injury

- Shear and stress overpressure waves directly result in TBI (concussive injury w/o direct blow to head)
  - Concussion
  - Edema
  - Hemorrhage
  - Diffuse Axonal Injury (DAI)
  - Brain Infarction secondary to gas emboli (blast lung)

# Brain Blast Injury

- Clinical manifestations
  - Headache, Seizures, Dizziness, Memory problems
  - +/- Loss of consciousness
  - Nausea/vomiting, Gait/balance instability, Difficulty concentrating
  - Visual disturbances, Tinnitus, Slurred speech
  - Extremity weakness or numbness
  - Disoriented, Irritability, Confusion

# Brain Blast Injury

- Under-diagnosis of mTBI in primary blast
  - 9/11 World Trade Center attacks study of 36 hospitals found 21/35 cases retrospectively diagnosed as probable TBI
  - Presence of more acute and life-threatening injuries (distracting injuries)

## Brain Blast Injury

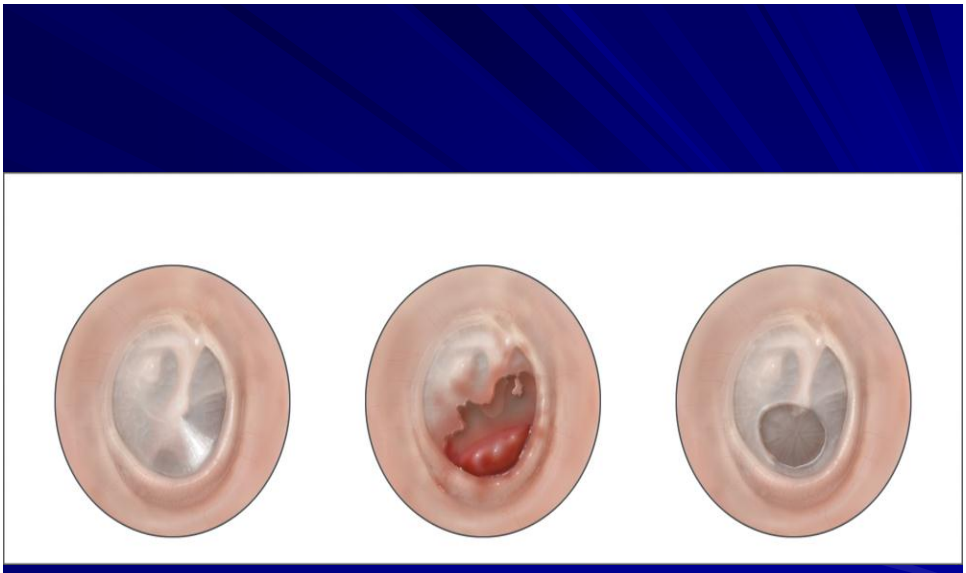
- Some cases may be misdiagnosed as post-traumatic stress disorder (PTSD) after a blast event, but may actually have post-concussion syndrome (PCS) and mTBI

## Auditory Blast Injury

- Tympanic membrane rupture is the most frequent primary blast injury
- Occurs at ~5 psi above atm. pressure (5-20 psi)
- Poorly correlates with blast injury elsewhere in the body; not useful as a predictive marker

# Auditory Blast Injury

- Symptoms include deafness, ringing in the ear, and vertigo
- Dislocation of middle ear bones may occur
- May have long term deafness



# Blast Lung Injury

- Second most frequent organ injured in primary blast
- Most common critical injury to persons close to blast epicenter
- Lung injury threshold has been reported to be ~40psi

# Blast Lung Injury Pathophysiology

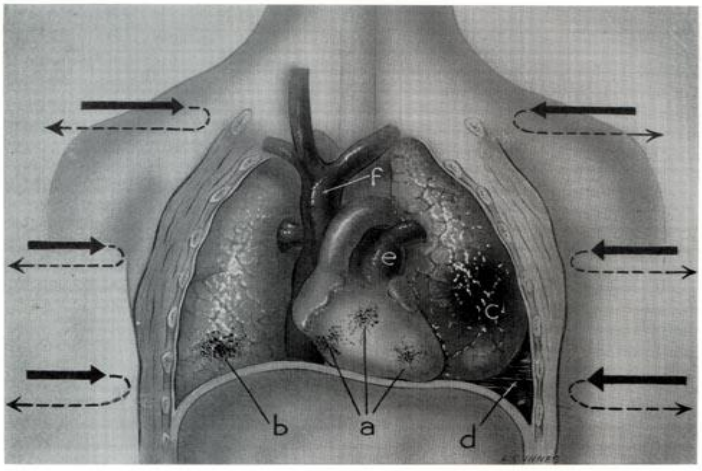



FIGURE 10.—Schematic showing of pathologic physiology of blast injury (wave of positive pressure shown by solid arrow, wave of negative pressure by dotted arrow): Petechial hemorrhage, cardiac (a), petechial hemorrhage, pulmonary (b), gross pulmonary hemorrhage (c), pleural hemorrhage (d), engorged pulmonary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

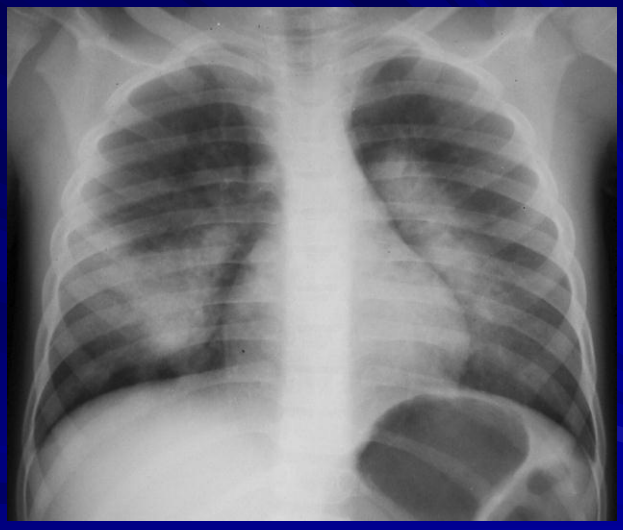
# Blast Lung Injury

- What happens?
  - Alveolar-capillary interface is disrupted
  - Bruising of the lung tissue (pulmonary contusion)
  - Blood in the lungs (hemothorax)
  - Air leak and compression of the lungs (pneumothorax and/or pneumomediastinum) and lung blebs
  - Rapidly progress to pulmonary edema

# Blast Lung Clinical Manifestations

- Cough (frothy/bloody)
- Difficulty breathing
- Retrosternal chest pain
- Rapid respiratory rate
- Cyanosis
- Decreased breath sounds
- Diffuse rhonchi/coarse
- Pulse oximetry low oxygen saturation
- Chest x-ray findings progressively worsen over 48 hours
- “bilateral butterfly wing infiltrates” or “white-out”
- Other findings: Stroke-like symptoms or death from brain/spinal cord blood vessel air embolism

Frontal chest radiograph obtained in a 24-year-old woman several hours after blast injury shows bilateral opacities in a butterfly distribution, representing pulmonary contusion.



Sosna J et al. Radiology 2005;237:28-36

Radiology

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# Cardiac Blast Injury

- Similar to blunt chest trauma
- Mainly contusions (bruises)
- Arrhythmias like ventricular fibrillation, ventricular tachycardia, bradycardia, and asystole

## Cardiac Blast Injury

- Hypotension and bradycardia
  - direct blast wave effect on disrupting compensatory vasoconstriction
- Death results from air emboli within the coronary circulation
- Cardiac monitoring is critical in this subset of patients

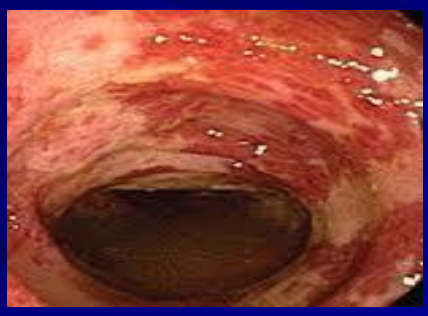
## Abdominal Blast Injury

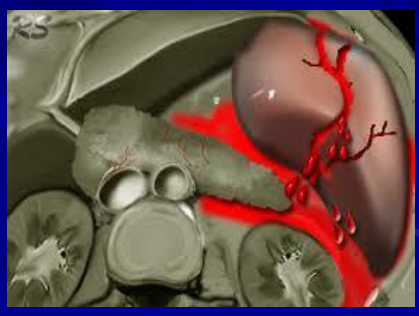
- More common in underwater blasts
- May result in overt bowel rupture
  - Ileocecal region is most susceptible
- Occult in presentation
  - Immediate or delayed rupture as a result of disrupted blood/oxygen supply

# Abdominal Blast Injury

- Sudden overpressure
- Constriction of the different tissue layers
- Intestinal wall separation, bleeding, clot formation, tissue death with subsequent bowel perforation
- Peritonitis results
  - a surgical emergency that can lead to death

Very high energy blasts or close proximity can result in rupture and bleeding of solid organs like the kidney, liver, and spleen





# Orthopedic Blast Injury (Traumatic Amputation)

- Blast wave that passes through shaft of long bones= bone failure and separates the fractured extremity
- Potential marker of severe blast exposure
- Rare in blast survivors
- Differs tertiary blast injury (secondary fragment or flying object)

# Other Primary Blast Injury

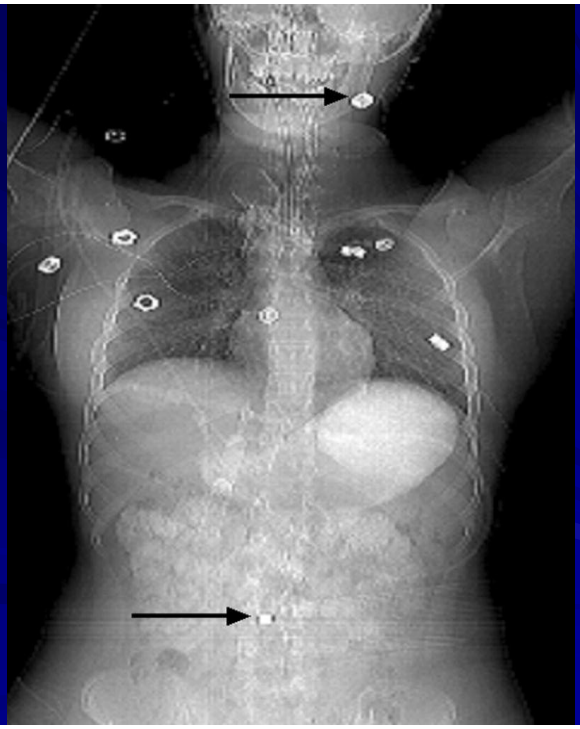
- Eye injuries (e.g. hyphema and globe rupture)
- Scrotal rupture
- Facial fractures



Medscape
www.medscape.com
A
B
Superior orbital fissure
C
Source: Expert Rev Ophthalmol © 2008 Future Drugs Ltd

# Secondary Blast Injury

- "Blast winds" or objects striking the victim
- Blunt trauma or penetration of energized, metallic fragments (shrapnel or debries)
- Penetrating injuries from fragments are the leading cause of death and injury in both military and civilian terrorist attacks

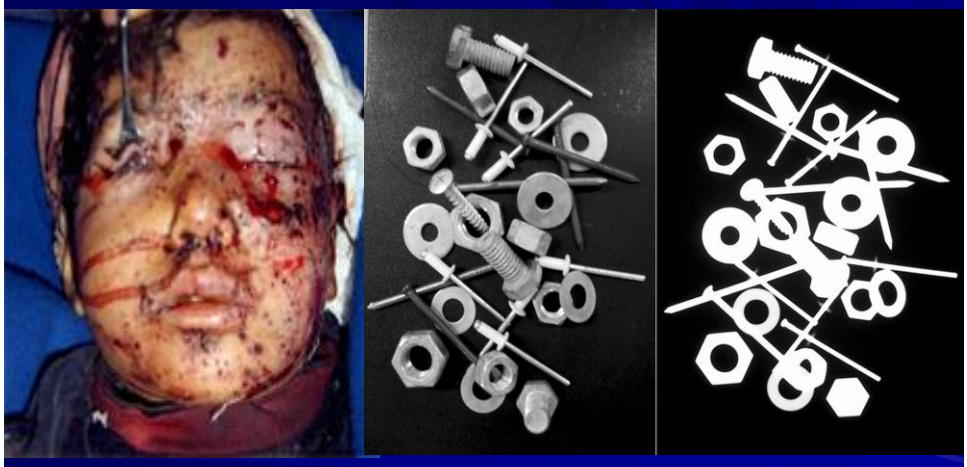


## Secondary Blast Injury

- Multiple fragments retained in the body
- Clothing offers slight protection against fragments
- Injuries mainly on exposed area of the body—hands, head and neck.

## Secondary Blast Injury

- Comminuted fractures of the longs bones
- Chronic disability and rehabilitation



## Tertiary Blast

- Acceleration-deceleration forces that occur as the “blast wind” propels the victim
- Victim being thrown into fixed objects
- Any body part can be involved
  - brain injury, traumatic amputation, and fractures

# Tertiary Blast

- Structural collapse is contributory
  - Large airborne fragments
  - Crush injury/Crush syndrome
  - Compartment syndrome
  - Extensive blunt trauma

## Quaternary Blast

- Explosion-related injuries or disease not related to primary, secondary, or tertiary injuries
- Thermal/chemical burns inhalational injury
- Asphyxiation

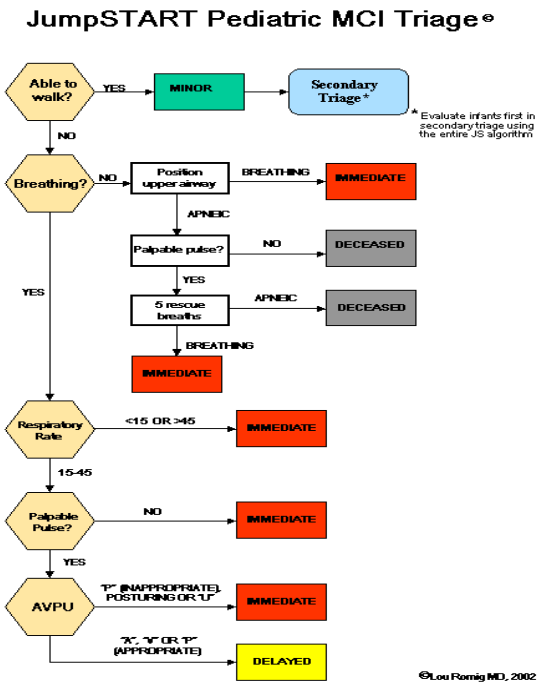
## Quaternary Blast

- Radiation exposure
- Psychological effects
- Infectious disease (Hepatitis B/C;HIV)

# What to do on scene?

- The most important priority after an explosion or terrorist bombing is scene control and safety
- Prehospital triage on scene? Second bomb?
- “Scoop and run” approach?
- The primary goal of EMS should be to protect the critically injured patient
- Rapidly evacuate most severely injured patient
  - Paramount that no casualty is overlooked

# Implications for children

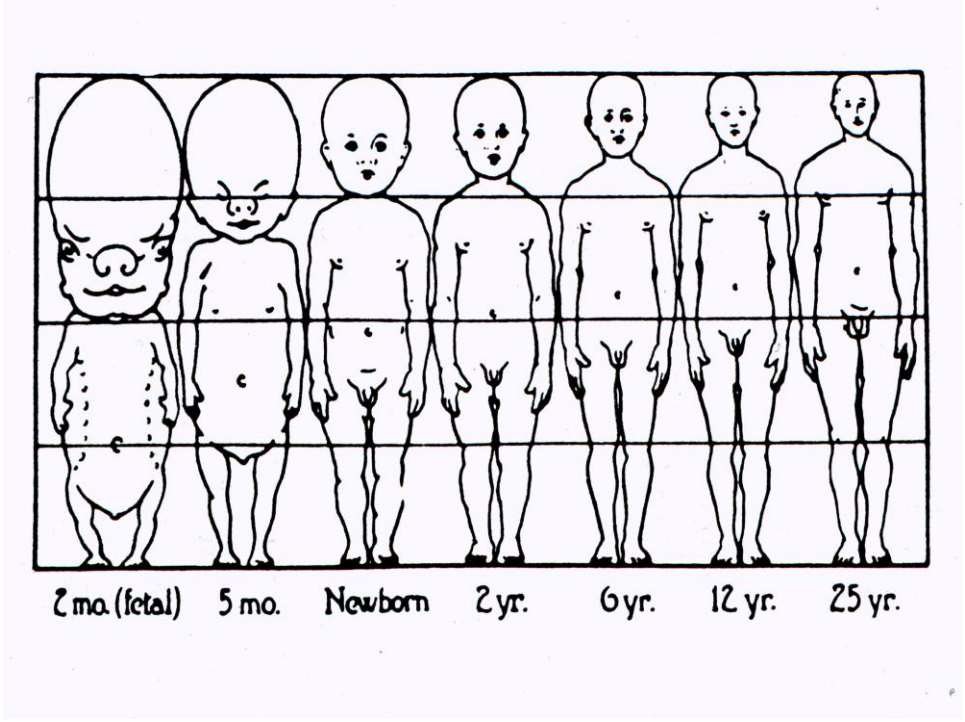



# PHYSIOLOGICAL CHARACTERISTICS

- Cardiopulmonary arrest in children is often secondary to an underlying respiratory problem
  - Paramount importance to focus on airway and respiratory status

# ANATOMICAL CHARACTERISTICS

- The head is the largest and heaviest in children
  - Vulnerable to injury in most traumatic mechanisms
  - Thin skull provides little protection to the brain
  - Weak neck muscles fail to stabilize the head and brain when subjected to external forces
  - Developing brain is subject to shearing forces and the effects of toxins crossing the blood-brain barrier



# ANATOMICAL CHARACTERISTICS

- Children have small body mass
  - Greater force transmitted to their body with resultant multiple organ injury
  - Thrown further with greater impact

# ANATOMICAL CHARACTERISTICS

- Children have large, less protected intra-abdominal organs (less abdominal fat and muscle)
  - Increase risk of liver, spleen, bowel injury secondary to even minor trauma

# ANATOMICAL CHARACTERISTICS

- Children have limited blood volume and fluid reserve
  - Higher risk for hypovolemic shock secondary to blood loss or excessive vomiting and diarrhea
    - 70 to 90ml/kg blood volume (age dependent)

# ANATOMICAL CHARACTERISTICS

- Children have unique body surface area and skin keratinization
  - High risk for hypothermia, dehydration, severe burns, and rapid systemic effects from toxin absorption

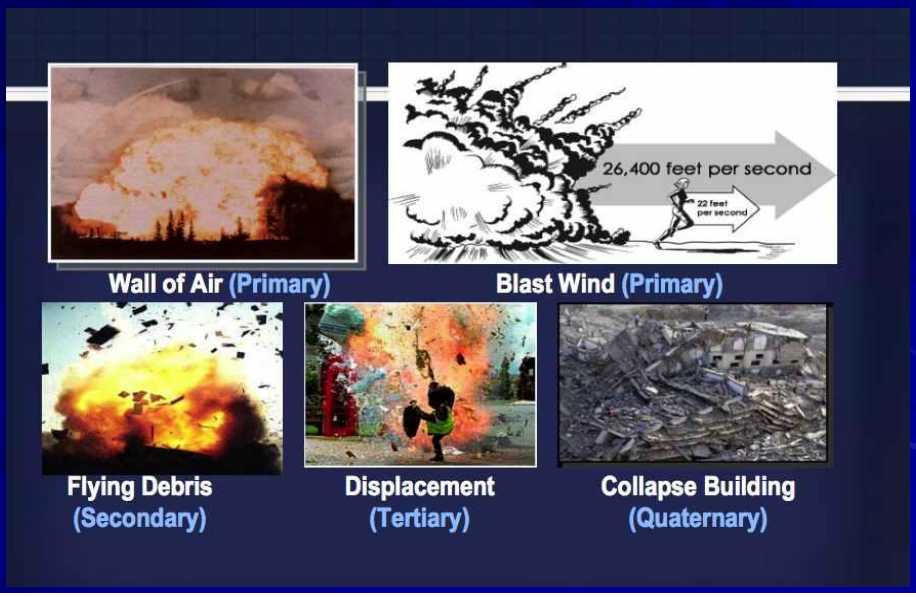
# PSYCHOLOGICAL CHARACTERISTICS

- Psychological responses to stress or injury in children vary
  - Based on developmental stage, age and cognition

# PRAGMATIC CONSIDERATIONS

- Treatment (Pediatric medication; weight-length based dosing)
- Child Identification, Supervision, & Reunification
- Psychological support and the Aftermath

# Summary




# Summary

- Children are <u>not</u> small adults and have unique characteristic that place them at risk during blast exposure
- TBI can manifest as a result of primary, secondary or tertiary blast injury

## True or False?

- Most terrorist attacks involve explosive devices? True
- Bombings are mainly directed at the government? False
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True

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- ARMY FIELD MANUAL 8-9
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# Brain Blast Injury

- Clinical manifestations
  - *Glasgow Coma Scale (GCS)*
    - *Mild TBI (*CDC definition)–At least 1 of the following inclusion criteria present:
      - *Any period of loss of consciousness (LOC) of less than 30 minutes and a Glasgow Coma Scale (GCS) of 13-15 following the LOC*
      - *Any loss of memory of the event immediately before or after the accident, with posttraumatic amnesia of less than 24 hours*
      - Any alteration in mental state at the time of the accident (e.g., feeling dazed, disoriented, confused)
    - Moderate to Severe TBI: GCS ≤ 12