

PaACEP Trauma Conference

Blast Injuries

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Edward Jasper, MD
Director, Center for Bioterrorism and Disaster Preparedness
Thomas Jefferson University / Hospital

Goals and Objectives

- Understand the different types of explosives and their potential effects
- Review the recent history of terrorism events utilizing explosive devices
- Know the categories of injuries to expect as a result of a blast mechanism

Introduction to Explosives

- An explosive is a substance that contains a great amount of stored energy that can produce an explosion, a sudden expansion of the material after initiation, usually accompanied by the production of light, heat, sound, and pressure
- The energy stored in an explosive material may be chemical energy, such as nitroglycerine, pressurized compressed gas, such as a gas cylinder or aerosol can, or nuclear, such as fissile isotopes of uranium-235 and plutonium-239

IED PIES Acronym

- Improvised explosive device (IED) - a homemade bomb constructed and deployed in ways other than in conventional military action
- An IED has four basic components described by the acronym PIES:
 - P** - Power Supply (electric or non-electric)
 - I** - Initiator - the component that starts the explosion reaction (e.g. blasting caps, flash bulbs, exposed filament)
 - E** - Explosive either high or low energy. Can be commercial such as ANFO, military such as Semtex or C4, or homemade explosives like HMTD or TATP
 - S** - Switch (mechanical or electrical)

Fragmentation vs Shrapnel

- Fragmentation (frag) – from pieces of the explosive device
 - Batteries
 - Switches
 - Casing
- Shrapnel – objects added to the bomb to increase damage
 - Nails
 - Ball bearings
 - Nuts

High vs Low Explosives

- Explosive materials may be categorized by the speed at which they expand
- Materials that detonate (explode faster than 3,300 feet/second) drive shock fronts and are said to be **high explosives (HE)**
 - Decompose almost instantaneously – requires no confinement – generates powerful blast overpressure wave
- Materials that deflagrate (burn/combustion < 3,300 feet/second) are said to be **low explosives (LE)**
 - Creates weaker overpressure, but enough to rupture container such as pipe bomb
- Create different patterns of injury

High vs Low Explosives

High Explosive: HE

- Nitroglycerin (NTG)
- Dynamite
- C4
- Ammonium nitrate/fuel oil (ANFO)
- Trinitrotoluene (TNT)
- Triacetone triperoxide (TAPT)

Low Explosive: LE

- Petroleum products ("Molotov cocktail")
- Gunpowder (blackpowder/smokeless powder)
- Pyrotechnics (fireworks)

Blast Pressure Waves

- Blast pressure effect – two distinct phases:
 - Positive pressure (overpressure) is the pressure that is produced by a blast that compresses the surrounding atmosphere
 - Negative pressure is when the positive pressure wave passes and the air fills the partial vacuum left behind
- Reflected pressure – in confined space detonations, blast waves can reflect off solid structures like walls and ceilings and amplify the strength of the initial shock wave

Another Classification of Explosives

- Explosives may also be categorized by their sensitivity:
- **Primary Explosives** - sensitive materials that can be initiated by a relatively small amount of heat or pressure are primary explosives
 - Lead Styphnate (blasting caps)
 - Peroxide based explosives (TATP, HMTD)
- **Secondary Explosives** - relatively insensitive to heat and pressure and usually require a significant stimulus like the detonation of a primary explosive
 - Dynamite, C4, TNT, PETN (detonating cord), RDX, HMX
- **Tertiary Explosives** – most insensitive to initiate
 - ANFO (ammonium nitrate fuel oil)
 - Requires detonator (primary explosive), plus booster like dynamite or C4 (secondary explosive booster charge) to detonate

Peroxide Explosives

- Hydrogen peroxide is most commonly available as a solution in water
- For consumers, it is usually available from pharmacies at 3 and 6 wt% concentrations
- 30 – 70 wt% solutions are used to make explosives
- Types recently used in terrorism attacks:
 - TATP - triacetone triperoxide
 - HMTD - hexamethylene triperoxide diamine







PETN

- Secondary explosive
- December 22, 2001 - Richard Reid (shoe bomber) Shoe bomber
 - TATP detonator
- Oct 29, 2010 - toner cartridge bomb
 - Five times the amount of PETN needed to level a house

Oklahoma City Bombing April 19, 1995

- Explosion killed 168 people, including 19 children
- 15 of the children were in the same day-care center
- Estimated 4,700 – 7,000 pounds of ANFO

Vehicle Bomb Explosion Effects

ATF	VEHICLE DESCRIPTION	MAXIMUM EXPLOSIVES CAPACITY	LETHAL AIR BLAST RANGE	MINIMUM EVACUATION DISTANCE	FALLING GLASS HAZARD
	COMPACT SEDAN	500 Pounds 227 Kilos <i>(in Trunk)</i>	100 Feet 30 Meters	1,500 Feet 457 Meters	1,250 Feet 381 Meters
	FULL SIZE SEDAN	1,000 Pounds 455 Kilos <i>(in Trunk)</i>	125 Feet 38 Meters	1,750 Feet 534 Meters	1,750 Feet 534 Meters
	PASSENGER VAN OR CARGO VAN	4,000 Pounds 1,818 Kilos	200 Feet 61 Meters	2,750 Feet 838 Meters	2,750 Feet 838 Meters
	SMALL BOX VAN (14 FT BOX)	10,000 Pounds 4,545 Kilos	300 Feet 91 Meters	3,750 Feet 1,143 Meters	3,750 Feet 1,143 Meters
	BOX VAN OR WATER/FUEL TRUCK	30,000 Pounds 13,636 Kilos	450 Feet 137 Meters	5,500 Feet 1,682 Meters	6,500 Feet 1,982 Meters
	SEMI-TRAILER	60,000 Pounds 27,273 Kilos	600 Feet 183 Meters	7,000 Feet 2,134 Meters	7,000 Feet 2,134 Meters

Source: Federal Alcohol, Tobacco and Firearms Agency website

Oklahoma City Injury Patterns

- 83 patients were hospitalized:
 - 98% soft tissue injuries
 - 24% severe lacerations
 - 57% fractures or dislocations
 - 53% head injuries
 - 37% eye injuries

Mumbai Terrorist Siege More Than 170 Dead

Access to Hospitals

- Hospitals and EMS are part of critical infrastructure
- Disguise as health care worker (hospital or EMS)
- Pretend to be a patient - the "victim" may be the bomber
- Disguise as EMS worker
- Employee

Recent Planned Domestic Attacks

No Plot is Cited, but U.S. Sounds a Holiday Alert

- Dec. 17, 2010 - Counterterrorism officials are tracking potential threats to the United States and Europe from al-Qaeda and affiliated groups during the holiday season
- They said that while they had not seen evidence yet of specific plots aimed at the United States, there was intelligence on attacks being planned against Europe during the holiday season

F.B.I. Says Oregon Suspect Planned 'Grand' Attack

- November 28, 2010 - Mohamed Osman Mohamud, a 19-year-old naturalized American citizen from Somalia, was arrested Friday by federal agents and charged with plotting to set off a bomb at a crowded Christmas-tree-lighting ceremony in downtown Portland
- About 10,000 people were in attendance
- The device the authorities say Mr. Mohamud sought to detonate was a fake bomb supplied by Federal Bureau of Investigation agents who had orchestrated a sting operation

Times Square Bombing Attempt

- May 1, 2010 - crude car bomb made from gasoline, propane, firecrackers and alarm clocks was discovered in a smoking Nissan Pathfinder in the heart of Times Square on May 1, 2010
- But the device failed to explode, and law enforcement teams tracked down a naturalized U.S. citizen from Pakistan, Faisal Shahzad, who was pulled from a Dubai-bound airliner at John F. Kennedy International Airport

Packages Bound for U.S. Contained Explosives

- October 29, 2010 - Two packages containing explosive devices originating in Yemen and addressed to two places of Jewish worship in Chicago were intercepted in Dubai and Britain, setting off a global terror alert
- The bomb found in England contained 400 grams (14 oz) of PETN. The one found in Dubai contained 300 grams (11 oz) of PETN
- No explosive packages were found to have reached the United States
- Possible probe of our defenses as well as an economic cost for screening and security

Public Transportation Bombings

March 11, 2004

Horror in Madrid: 191 Die More Than 1,600 Hurt

July 7, 2005 51 Die in London Bomb Blasts

- Rumors of over 1,000 victims initially – final number about 700 were treated for injuries
- Royal London Hospital:
 - 27 admissions for surgical/intensive care
 - 8 immediate care
 - 11 amputations
 - 2 deaths (1 intra operative, 1 post op)
- 167 discharged
 - 39 lacerations requiring sutures
 - 78 assessed for inhalational injury
 - 17 TM perforations (8 bilateral/9 unilateral)
 - Multiple abrasions, burns, foreign bodies, sprains

At Least 183 Killed in Indian Train Blasts

- July 11, 2006 – A series of eight explosions at seven train stations killed at least 183 people on crowded commuter trains and stations in the Indian financial capital of Mumbai (Bombay)

Moscow Bombing: Carnage at Russia's Domodedovo Airport

- January 24, 2011 - A bomb attack at Moscow's Domodedovo airport has killed at least 35 people and injured more than 100 - many of them critically, officials say
- The explosion occurred in the international arrivals hall (luggage collection area) in a public area to which people who are not passengers have free access

BLAST INJURIES

Types of Blast Injuries

- Primary
 - Due to direct effect of pressure
- 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
- Quinary
 - Hemodynamic instability and hyperinflammatory state
 - Thought to be from blast materials inhaled or absorbed
 - Fragments of human remains as secondary projectiles

Primary Blast Injury

- Unique to high explosives
- Due to impact of over-pressurization wave with body surfaces
- Most commonly involve air-filled organs and air-fluid interfaces
 - Middle ear
 - Lungs
 - Gastrointestinal tract
- Types of injuries
 - Blast lung
 - Tympanic Membrane (TM) rupture
 - Abdominal hemorrhage and perforation
 - Globe rupture
 - Traumatic brain injury (TBI) without physical signs of head injury

TM Injury

- TM - structure most frequently injured by blast
 - TM rupture
 - Ossicle dislocation
 - Disruption of oval or round window
- Symptoms may include hearing loss, tinnitus, vertigo, bleeding from external canal
- TM rupture is sensitive marker, but **absence does not exclude other organ injury**

Blast Lung Injury

- Lung – 2nd most susceptible organ to blast injury
- Most common fatal primary blast injury among initial survivors
- Pulmonary barotrauma includes
 - Pulmonary contusions
 - Systemic air embolism

Blast Lung Injury

Should not rely on TM rupture to predict lung injury:

- TM perforations are found in only 60% of patients with clinically significant injuries
- Clinically significant injuries are present in less than 30% of patients with TM perforations

Blast Lung Injury

- 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
- Radiographic findings
 - Bilobar “butterfly” pattern
 - Pneumothorax or hemothorax
 - Pneumomediastinum and subcutaneous emphysema

Blast Lung Management

- In general, managing BLI is similar to caring for pulmonary contusion, which requires judicious fluid use and administration ensuring tissue perfusion without volume overload
- All patients with suspected or confirmed BLI should receive supplemental high flow oxygen sufficient to prevent hypoxemia (delivery may include non-rebreather masks, continuous positive airway pressure, or endotracheal intubation)
- Clinical evidence of or suspicion for a hemothorax or pneumothorax warrants prompt decompression

Blast 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 less likely
- Signs and symptoms
 - Abdominal pain, nausea, vomiting, hematemesis
 - Rectal pain and tenesmus
 - Testicular pain
 - Unexplained hypovolemia

Other Primary Blast Injuries

- Eye
 - Globe rupture, retinitis, hyphema, lid laceration, traumatic cataracts, injury to optic nerve
 - Signs and symptoms include eye pain, foreign body sensation, blurred vision, decreased vision, drainage
 - Up to 28 percent of blast survivors may have serious eye injuries, particularly if the blast caused shattering glass (secondary blast injuries).
- Brain
 - TBI due to concussion or barotrauma of gas embolism
 - Signs and symptoms include headache, fatigue, poor concentration, lethargy, anxiety, and insomnia

Secondary Blast Injury

- Due to flying debris and bomb fragments
- Penetrating ballistic or blunt injuries
 - Leading cause of death in military and civilian terrorist attacks except in cases of major building collapse
 - Wounds can be grossly contaminated
 - Consider delayed primary closure and tetanus vaccinations

Tertiary Blast Injuries

- Due to persons being thrown into fixed objects by wind of explosions
- Also due to structural collapse and fragmentation of building and vehicles
- Structural collapse may cause extensive blunt trauma
 - Crush syndrome
 - Compartment syndrome

Quaternary Blast Injuries

- Explosion related injuries or illnesses not due to primary, secondary, or tertiary injuries
 - Exacerbations of preexisting conditions, such as asthma, COPD, CAD, HTN, DM, etc.
 - Burns (chemical and thermal)
 - Toxic inhalation (e.g. asbestos)
 - Radiation exposure (not likely chemical or biological in the bomb – but can be released simultaneously)
 - Asphyxiation (carbon monoxide and cyanide)
 - Alcohol and substance abuse, Mental Health

Quinary Blast Injuries

- New category – two types:
 - Hyperinflammatory state with fever, sweating and low CVP
 - Fragments of human remains

General Considerations

- Half of all initial casualties seek medical care over first hour
- Expect upside down triage
 - Most severely injured arrive after less injured who bypass EMS and self-transport to closest hospitals
- Secondary devices
 - Initial explosion attracts law enforcement and rescue personnel who will be injured by second explosion

Special Considerations

- Pregnancy
- Children
- Elderly
- Disabled
- Language barriers
- Psychological issues

Next Steps

- Develop a written disaster plan – department representatives
- Train, Review and Exercise the plan – weather emergencies, special events



edward.jasper@jefferson.edu
