Bombs, Explosions and Preparedness: A New Role for Public Health and First Responders

Satellite Conference and Live Webcast

Tuesday, March 27, 2007

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Produced by the Alabama Department of Public Health
Video Communications and Distance Learning Division

Faculty

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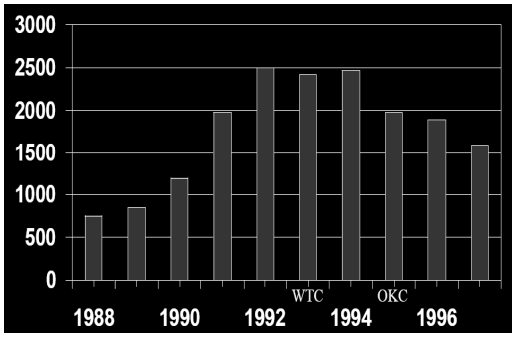
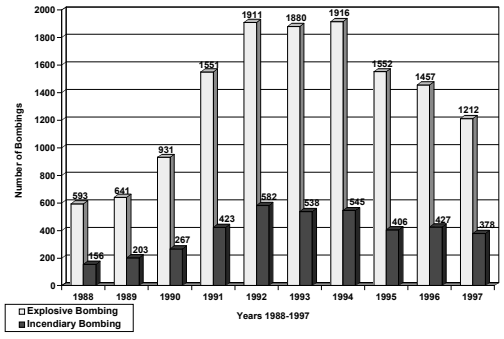
Program Objectives

- **Describe important historical events involving explosions.**
- **Discuss different clinical aspects of blast injuries.**
- **Describe public health and first responder activities in reaction to explosions and blasts.**

FBI Reported Bombings, 1988-1997



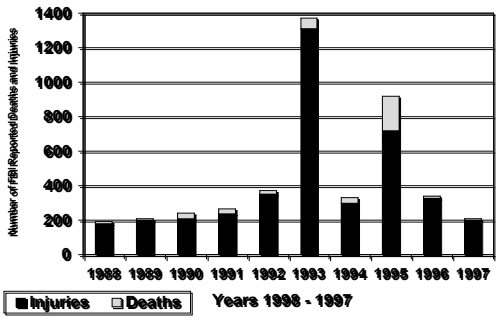
FBI Bombing Database 1988-1997



FBI Bombing Database 1988-1997

- **17,579 bombings**
- **Numbers doubled over the 10 year period**
- **Number of bombing peaked in 1992**
- **78% were explosives and 22% were incendiaries**

FBI Bombing Database 1988-97



FBI Bombing Database 1988-1997

- 427 deaths with a peak in 1995 (Oklahoma City bombing)
- 4,063 bomb-related injuries
- Incendiary bombs caused more injuries than explosives

Special Characteristics of Bombing Victims

- Victims of terrorist bombings (906) were compared with 55,033 casualties of non-terror related trauma.

Special Characteristics of Bombing Victims

- Bombing resulted in significantly different:
  - Injury complexity
  - Increased severity
  - More body regions involved
  - Enhanced use of intensive care
  - Prolonged hospital stay
  - More surgical interventions
  - Increased hospital mortality

Discovery

- A Mongol bomb thrown against a charging Japanese samurai during the Mongol invasions of Japan, 1281.

Discovery

- Believed to be discovered in China in the 10th century
- Called black powder or gun powder
  - Charcoal
  - Potassium nitrate
  - Sulfur
- Used for signals and fireworks
- Then used in warfare

Spread

- Brought to Europe by an English monk named Roger Bacon who published the formula.
- Developed further by a German Franciscan monk, Berthold Schwarts.

Nitroglycerin

- Invented by Italian chemist Ascanio Sobrero in 1846
- Liquid form
- Ignites and explodes spontaneously

Dynamite

- Invented by Alfred Noble
- Added silica to liquid nitroglycerine making the more malleable dynamite
- Also invented blasting caps that were made with a fuse and gunpowder

Ammonium Nitrate/Fuel Oil (ANFO)

- Fuel oil (diesel but can be kerosene or molasses)
- 80% of explosives used in the USA
- High explosive
  - Requires a booster

Texas City Disaster 1947

- Seven KiloT of ANFO exploded on board of SS Grandcamp in the port killing 581 people.

1983 - US Marine Barracks and Embassy Bombings, Beirut

- At 6:20 a.m. a yellow truck drove into the US Marine headquarters.
- Truck carried explosives equivalent to 12,000 pounds of TNT.
- This initial explosion was coupled with another explosion 20 seconds later at the French Marine barracks.
- 307 people died and 75 were injured.

1995 - Oklahoma City Bombing

- Ryder truck detonated in front of building containing 2,300 kg of explosive material.
- Blast destroyed or damaged 324 buildings within radius of sixteen-blocks.
- 168 confirmed dead.
- 153 victims had been treated at St. Anthony Hospital, eight blocks from the blast.

U.S. Embassy Bombings Dar es Salaam, Tanzania and Nairobi, Kenya August 7, 1998

- Car bombs in vehicles, each adjacent to the embassies, were detonated simultaneously at 10:45 a.m.
- Total of 257 people were killed and 7,000 wounded.

World Trade Center September 11, 2001

- Both Twin Towers of the World Trade Center were destroyed.
- 25 surrounding buildings were damaged.
- 2749 people were killed in WTC and on board both American Flight 11 and United Flight 175.

Iraq 2003 - Present

- Bombing tactics have largely been composed of military bombings, suicide bombings, and car bombings.

Iraq 2003 - Present

- As of late 2003, 40 to 60 percent of all attacks began with an IED.
  - Some of these attacks included direct fire attacks immediately following the detonation of the device.
  - More and more IEDs were subsequently being used as a stand-alone means to engage a convoy.

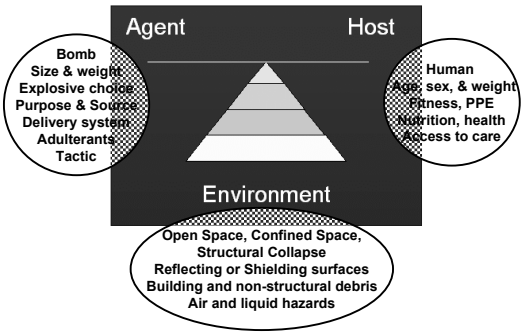
Madrid Commuter Train March 11, 2004

- Using 13 IEDs in backpacks, ten explosions occurred aboard four commuter trains over 3 minutes.
- All trains were traveling on the same line and in the same direction.
- 191 people were killed and 2050 were injured.

London Underground and Double Decker Bus, July 7, 2005

- Three suicide bombs exploded within 30 seconds of each other on the underground system.
- Almost one hour after the underground explosions, a suicide bomb was detonated on a double decker bus.
- 52 people were killed and around 700 were injured.

Bomb-Injury Threat Model



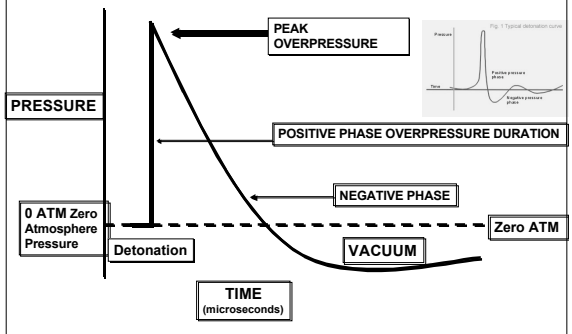
Explosives

- Chemical compound that is able to release stored energy in the form of rapidly expanding gases.

High Explosives

- Stored energy is released rapidly
- Detonation
- Examples: TNT and dynamite

Idealized Blast Overpressure Waveform Seen Only in High-order Explosives (HE)



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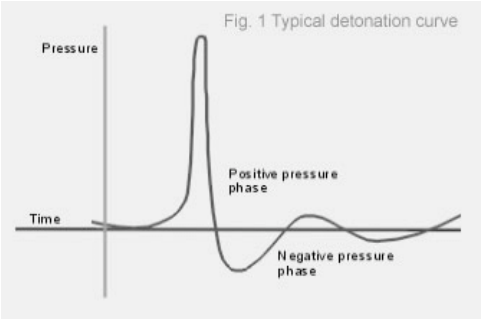


Low Explosives

- Stored energy is released slowly
- Combustion or deflagration
- Examples: gun powder, fuel
- No blast wave or over pressurization
- Injury results from:
  - Thermal burns,
  - Ballistic (shrapnel)
  - Suffocation (fumes and toxins)

Host

- Age
- Sex
- Height
- Medical history
- Access to care

Environment

- Open space
- Enclosed or confined space
- Structural collapse

Open Space

- Potential for shrapnel to travel a large distance (>100 m)
- Less primary blast injuries

Enclosed Space

- Increased mortality
- Increased blast pressure
- Complicated rescue

Structural Collapse

- Increased mortality:
  - Primary blast wave
  - Tertiary and quaternary injuries
- Crush syndrome

Impact of Building Collapse on Outcome In Oklahoma City Terrorist Bombing, 1995

Casualty Location	No. of Casualties	No. of Dead(%)	No. of Survivors	No. of Survivors Hospitalized (%)
Collapsed	175	153 (87)	22	18 (82)
Uncollapsed	186	10 (5)	176	32 (18)
Total	361	163 (45)	198	50 (25)

Madrid Bombing

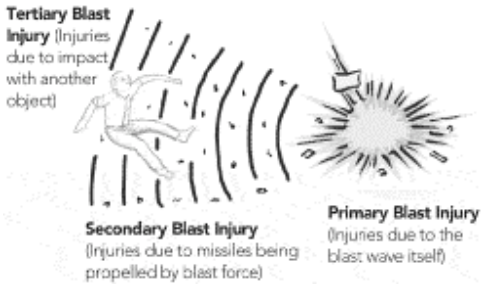
- Rupture of the tympanic membranes occurred in 99 of 243 victims
- Chest injuries in 97/243 victims
- Shrapnel wounds in 89/243
- Fracture in 44
- Burns in 45
- Eye injuries in 41
- Abdominal injuries in 12
- Traumatic amputations in 5

Immediate Effects of Blast and Explosions

- Primary - direct effects (e.g., overpressurization and underpressurization)
  - Rupture of tympanic membranes
  - Pulmonary damage
  - Rupture of hollow viscera
- Secondary
  - Penetrating trauma
  - Fragmentation injuries

Immediate Effects of Blast and Explosions

- Tertiary - effects of structural collapse and of persons being thrown by the blast wind
  - Crush injuries and blunt trauma
  - Penetrating or blunt trauma
  - Fractures and traumatic amputations
  - Open or closed brain injuries
- Quaternary - burn, asphyxia, and exposure to toxic inhalants



Primary Blast Injuries

- Result from overpressurization or underpressurization relative to atmospheric pressure
- Result from the interaction of high frequency stress waves and low frequency shear forces

Primary Blast Injuries

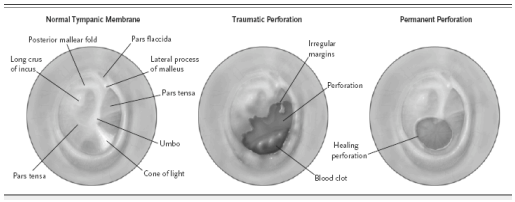
- Affect air-filled organs or air-fluid interfaces
- Rupture of tympanic membranes, pulmonary injury, air embolization and rupture of hollow viscera are the most common patterns

Tympanic Membrane Rupture

- Occurs at the lowest pressure (5 psi)
- May be bilateral
- May be the earliest sign to look for
  - Deafness, tinnitus and vertigo
- If more severe, may cause dislocation of the oval, round window or the ossicles
  - Permanent hearing loss
- Other organs need higher pressures (56-76 psi) so if the TM is intact, they are unlikely

Tympanic Membrane Rupture

Normal and Perforated Right Tympanic Membranes



The drawing of a traumatic perforation shows an irregular margin or rim with blood or a blood clot, and the drawing of a permanent central perforation shows a tympanocele.

Pulmonary Injuries

- Second most common primary blast injury
- Hemorrhage
  - Pulmonary contusion (appearing as a bihilar "butterfly" pattern on chest radiographs)
  - Pneumothorax
  - Hemothorax
  - Pneumomediastinum
  - Subcutaneous emphysema

Pulmonary Injuries

- Onset of symptoms is commonly within minutes.
- Body armor protects from penetrating (secondary) but not primary blast injuries.
- Early onset pulmonary edema carries a grave prognosis.

TM Perforation - Pulmonary Injury

- Among 17 critically ill victims with pulmonary injuries from the blast:
  - 13 had ruptured tympanic membranes and 4 did not
  - Rupture of tympanic membranes occurred in 18 of 27 critically injured victims
    - 17 of these were bilateral

Data from Madrid

Screening

- 647 survivors of explosions on buses used immediate radiography of the chest to screen for pulmonary injuries from the blasts.
- Primary injuries, in some form, were found in 193 persons:
  - 142 had isolated perforation of the eardrum.

Screening

- 51 had other forms of primary blast injuries:
  - 18 with isolated pulmonary injuries
  - 31 with combined otic and pulmonary injuries
  - Two with intestinal injuries

Visceral Injury

- Visceral injury is third most common primary blast injury.
- Rupture of the colon and, less frequently, the small intestine may occur as an immediate result of a blast.
- Mesenteric ischemia or infarct can cause delayed rupture of the large or the small intestine; these injuries are difficult to detect initially.

Other Injuries

- Ruptured globe or serous retinitis
- Concussion
- Air embolism may be seen and can present as stroke, MI, acute abdomen, blindness, deafness, spinal cord injury, or claudication

Secondary Injuries

- Penetrating injuries from:
  - Primary fragments (fragments that are part of the weapon)
  - Secondary fragments (those that result from the explosion)

Ocular war injuries in Iraq are common

Tertiary Injuries

- Caused by trauma from falling objects or from bodies being thrown against other objects
  - Blunt and penetrating injuries
  - Crush syndrome and secondary rhabdomyolysis
  - Open or closed head injuries

Crush Syndrome

- Entrapment increases mortality
- Rhabdomyolysis: Myoglobinuric renal failure and hyperkalemia

Crush Syndrome

Statistics Related to Major Earthquakes in the Past 18 Years

Location and Year	Death	Crush Victims
Spitak, Armenia, 1988	25,000	600
Northern Iran, 1990	>40,000	?
Kobe, Japan, 1995	5,000	372
Marmara, Turkey, 1999	>17,000	639
Chi-Chi, Taiwan, 1999	2,405	52
Gujarat, India, 2001	20,023	35
Boumerdes, Algeria, 2003	2,266	20?
Bam, Iran, 2003	26,000	124
Kashmir, Pakistan, 2005	>80,000	118
Total	>217,000	>1900

Rhabdomyolysis

- Secondary complication of crush syndrome
- Myoglobinurea and CK elevation
- Treatment is IV hydration, urinary alkalinization (with mannitol)

Quaternary Injuries

- Burns (chemical or thermal)
- Toxic inhalation of carbon monoxide or hydrogen cyanide gas
- Exposure to radiation
- Inhalation of dust containing coal or asbestos
- Exacerbation of chronic illnesses

Carbon Monoxide - Mechanism

- Binds hemoglobin to form carboxyhemoglobin that is unable to carry oxygen
- Uncouples oxidative phosphorylation

Carbon Monoxide - Clinical

- Neurological manifestations
- Cardiovascular manifestations
- Gastrointestinal manifestations

Carbon Monoxide - Labs

- Carboxyhemoglobin level
- Creatine kinase
- EKG, CXR

Hydrogen Cyanide - Mechanism

- Inhibits cytrochrome oxidase and uncouples oxidative phosphorylation
- Cells are unable to use oxygen
- Anaerobic metabolism prevails

Hydrogen Cyanide

- Clinical:
  - Neurological
  - Cardiovascular
  - Bitter almond: only 60% of population can detect
  - Cherry red skin, fundoscopic exam
- Labs:
  - Lactic acid
  - O_2 extraction and venous O_2 saturation

Exacerbation of Chronic Illnesses

- Asthma and COPD
- Diabetes Mellitus
- Hypertension
- Coronary artery disease
- Peptic ulcer disease
- Alcohol and substance abuse
- Mental health

Prehospital

- Airway
- Breathing
- Circulation
- Triage categorization
- Did the blast occur in an enclosed setting?
- Regular trauma/burn protocols
- Radiation survey
- Secondary device survey
- Survey for chemical contamination

Prehospital

- Incident command
- Securing the area
- Judicious use of IV fluids:
  - Overzealous fluid administration may worsen primary pulmonary injury or even bleeding.
- Cautious mechanical ventilation:
  - Mechanical ventilation and positive pressure may increase the risk of alveolar rupture and air embolism.

Prehospital Special Considerations

- Cautious air transport
- Air embolization:
  - Place patient in a prone left lateral position

Triage Categorization

- Red – Immediate
- Yellow – Delayed
- Black – Dead or expectant
- Green – Minimal

Transport

- Transport to the nearest facility of red patients.
- Green patients should be directed to other hospitals that are further away and that are not necessarily level I trauma centers.

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

- Patients with normal CXR and ABGs, who have no complaints that would suggest BLI, may be discharge after 4-6 hours of observation.

Blast Lung Injury

- Management similar to pulmonary contusions
- Complex fluid management
- Mechanical ventilation will increase the risk of air embolization

Management of Secondary Injuries

- As per protocol
- Watch for unusual shrapnel such as nails and bolts

Management of Tertiary Injuries

- As per trauma protocols
- Look for crush syndrome especially in structural collapse:
  - Myoglobinurea
  - Renal failure
  - Hyperkalemia

Major Steps in Treating Patients With The Crush Syndrome

- Consider the importance of early fluid administration in the field.
  - Initiate an infusion of isotonic saline at the earliest convenience, followed by hypotonic saline-alkaline solution.
  - In patients with adequate urinary flow, add mannitol to the solution.
  - Avoid empirical administration of potassium-containing fluids.

Major Steps in Treating Patients With The Crush Syndrome

- Closely monitor each patient's fluid intake and urinary output.
  - Administer up to 6 to 12 liters of appropriate fluids per day.
  - Remember that urinary output may be substantially lower than the amount of administered fluid.
  - Amount of fluid defined by the basis of the clinical course or central venous pressure measurements.

Major Steps in Treating Patients With The Crush Syndrome

- Correct electrolyte abnormalities.
  - Hyperkalemia is often fatal and should be corrected vigorously.
  - Hypocalcemia should be corrected only if it causes symptoms.
  - Remember that virtually any other electrolyte disturbance may occur as well and should be treated.

Major Steps in Treating Patients With The Crush Syndrome

- Consider dialysis as a lifesaving procedure.
- Begin dialysis when indicated by the presence of any of the following: oliguria or anuria, volume overload, or biochemical abnormalities such as severe uremia, hyperkalemia, and acidemia.

Major Steps in Treating Patients With The Crush Syndrome

- Consider the initiation of prophylactic dialysis in patients at high risk for hyperkalemia.
- In order to estimate logistic needs, remember that the average duration of dialysis will be 13 to 18 days.
- Consider continuing dialysis support until patients' kidney function has recovered.

Management of Crush Syndrome

- IVF: Start in the field
- Urinary alkalinization:
  - Myoglobinurea, Urine pH>7
- Mannitol
- Hemodialysis:
  - Anuric patients, acidemic patients
  - Correction of electrolyte abnormalities
  - Advanced surge capacity planning

Management of Quaternary Injuries

- Inhalational injuries
- Carbon monoxide
- Hydrogen cyanide
- Contamination with radionuclides

Carbon Monoxide

- 100% oxygen therapy
- Hyperbaric oxygen therapy

Cyanide Antidotes

The Lilly kit

- Amyl nitrite pearls
- Sodium nitrite
- Sodium thiosulfate

Hydroxocobalamin

- Bind cyanide to form cyanocobalamin or Vitamin B12
- Recently FDA approved

Dirty Bombs

- Scene decontamination:
  - Removal of clothes
  - Soap and water
  - Life saving procedure should precede decontamination

Radiopharmaceuticals

• Radionuclide	• Medication
– Iodine	– KI (potassium iodide)
– Transuranics such as Plutonium & Americium	– Zn-DTPA Ca-DTPA
– Uranium	– Bicarbonate
– Cesium, Rubidium, Thallium	– Prussian Blue [Ferrihexacyano-Ferrate(II)]
– Tritium	– Water

Mental Health Background

- Mental illness is common after disasters in victims and first responders.
- Psychopathology similar in different cultures.
- Responses and coping mechanisms may be different amongst different people or cultures.

Long-term Effects After the Tokyo Sarin Attack

Residual symptoms after 1 year (n=303)

Eye symptoms	56 (18.5%)
Fear of the subway	39 (12.9%)
Easy fatiguability	36 (11.9%)
Fear concerning escape from the attack	35 (11.6%)
Flashbacks	32 (10.6%)
Headache	26 (8.6%)
Depressive feelings	24 (7.9%)
Lack of concentration	23 (7.6%)

Reactions to Stress

- Occur in stages, each one characterized by a specific psychological mechanism.
- Symptoms include:
  - Flashbacks
  - Difficulties in remembering
  - Avoidance of stimuli
  - Blunting of responses
  - High arousal level
  - Obsessive ruminations

Clinical Illnesses

- Post Traumatic Stress Disorder (PTSD)
- Depression
- Anxiety
- Alcohol abuse

Special Aspects - Victims

- Events are unexpected
- Often affect civilians
- Bombing victims sustain traumatic disfiguring injuries

Special Aspects - Responders

- Bombing victims sustain traumatic disfiguring injuries
- Scene may be hazardous
  - Structural collapse
  - Secondary devices
  - Inhalational injuries from potential toxins
- Distress from inability to save entrapped victims

World Trade Center

- After Sept. 11, at least three New York men involved in rescue and recovery efforts have committed suicide:
  - James Kay Jr., an emergency medical technician, shot himself early last year.
  - Six months later, Daniel Stewart, another EMT, hanged himself.

Interventions

- Increased awareness
- Debriefing
- Mental health specialist
  - Screening
  - Psychotherapy
  - Pharmacologic therapies
  - Other methods

Physical Rehabilitation for Head Injury

- Constrain-induced therapy
- Optimal at 3 months after what injury
- University of Alabama at Birmingham
  - Taub Therapy Clinic

Upcoming Programs

Pandemic Influenza:
Alabama Schools Need to Plan Now
Monday, April 2, 2007
3:30 - 5:00 p.m. (Central Time)

For complete list of upcoming programs visit our website www.adph.org/alphtn