Explosive Threats

Pacific Emergency Management, Preparedness and Response
Information Network and Training Services
(Pacific EMPRINTS)

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Explosive Threats: Bombings

- Bombings are the most common and most lethal terrorist tactic in recent history.
- Responsible for 57% of incidents and 54% of fatalities since 1968.
- Notable U.S. bombings:
  - Oklahoma City, 1995: 167 killed, 500 injured.
  - World Trade Center Bombing, 1993: 6 killed, 1042 injured.

Oklahoma City Bombing

"Incidents by Tactic." *Memorial Institute for the Prevention of Terrorism: Knowledge Base.* July 1, 2007. http://www.tkb.org/IncidentTacticModule.jsp.

Explosive Threats: Accidental & Industrial

- Accidental and Industrial Explosions:
  - Texas City Disaster, 1947: 600 killed, 2,000 injured.
  - Henderson Nevada Rocket Fuel Explosion. 1985: 2 killed, 300 injured.
  - Osan Air Base, 1986: 14 killed, 12 injured.

Osan Air Base Explosion

Types of Explosive Agents

- **High Explosives:**
  - Example: TNT/dynamite.
  - Detonation occurs faster than the speed of sound, produces heat and gas, blast wave.

Boxed improvised explosive device

- **Low Explosives:**
  - Example: Gunpowder
  - Burn rather than detonate, with slower velocity.
  - The most common form of terrorism.

Bomb Threat Injury Model

- **Host:**
  - General health status
  - Age
  - Sex
  - Mental health background
  - Socioeconomic status
  - Access to immediate medical care

Bomb Threat Injury Model

- **Agent:**
  - Military ordnance:
    - Predictable pattern of injury.
    - Uses advanced technology, targeted delivery systems.
    - Uses high explosives.
  - IED (Improvised Explosive Device):
    - Any materials used.
    - Lacks sophisticated weaponry.
    - Relies on human carriers.
  - Industrial or accidental explosions

Bomb Threat Injury Model

- **Environment:**
  - Open space:
    - Blast wave dissipates rapidly.
    - More injuries due to flying objects and shrapnel.
  - Confined space:
    - Shock waves amplified.
    - More severe lung and gastrointestinal injuries.
  - Structural collapse:
    - Confined space blast injuries as well as fractures and crush injuries.

At the Scene

- The area is a crime scene.
- Scene Safety:
  - Secondary devices.
  - Perpetrators at the scene.
  - Exposure to inhaled toxins, biological, and chemical agents should be considered in industrial and terrorist explosions.
  - Shrapnel.
  - Building collapse.

Personal Protective Equipment

- Coveralls
- Heavy coat
- Heavy gloves
- Steel-toed boots
- Hard hat
- Eye protection
- Dust particle mask
- Breathing apparatus for toxic fumes

Triage

- 20% of patients will have critical injuries.
- Overtriage may harm those with critical but salvageable injuries.
- 75% of victims may self-refer to hospitals.

Types of Blast Injury

Type of Injury	Mechanism of Injury
Primary	Caused by the effect of the blast wave's extreme pressure differential on the body. Occurs primarily in gas-filled organs such as the lung, middle ear, and bowel.
Secondary	Caused by flying debris and fragments propelled by blast winds. Produces penetrating injuries and at close distances causes limb amputation or total body disruption.
Tertiary	Results from victim being thrown against a stationary object by the blast wind.
Quaternary	Consists of injuries suffered from all other effects of the blast including crush injuries from collapsing structures, inhalations of toxic gases and debris, thermal burns, exposure to radiation, or exacerbation of prior medical illnesses.

Blast Lung

- Most common fatal injury among survivors of an explosion.
- Blast wave causes tearing, hemorrhage, contusion, and edema.
- Symptoms: dyspnea, hemoptysis, cough, and chest pain.
  - Often occurs without obvious external chest injuries.
- Signs of blast lung: tachypnea, hypoxia, cyanosis, apnea, wheezing, decreased breath sounds, and hemodynamic instability.
- Pathology: bronchopleural fistula, air emboli, and hemothoraces or pneumothoraces.

"Blast Lung Injury: What Clinicians Need to Know ." *Centers for Disease Control and Prevention.* July 7, 2005. http://www.bt.cdc.gov/masscasualties/blastlunginjury.asp

Blast Lung: Diagnostic Evaluation

- Chest radiograph recommended for anyone exposed to the blast.
- X-ray may reveal "butterfly" pattern of lung damage.
- Other methods: arterial blood gases, computerized tomography, and doppler technology.

"Blast Lung Injury: What Clinicians Need to Know." *Centers for Disease Control and Prevention.* July 7, 2005. http://www.bt.cdc.gov/masscasualties/blastlunginjury.asp

Blast Lung: Management

- Initial triage, resuscitation, treatment and transfer follow standard protocols.
- Prophylactic chest tube recommended before general anesthesia or air transport.
- If blast lung confirmed/suspected, provide supplemental oxygen flow via NRB mask, CPAP, or ET tube.
- If secondary edema, injury, or massive hemoptysis, or impending airway compromise occurs, secure the airway.
- Evidence of hemothorax or pneumothorax warrants decompression.
- If ventilatory failure occurs or is eminent, patients should be intubated:
  - Mechanical ventilation and positive pressure increases risks of alveolar rupture, pneumothorax, and air embolism.
- If air embolism suspected:
  - Administer high oxygen and position in a prone, semi-left lateral, or left lateral position.

Abdominal Injuries

- Similar to blast injuries in thoracic cavity.
- Gas-containing structures, particularly the colon, are vulnerable.
  - Injuries may occur without external signs.
  - Perforations may be delayed 24-48 hours.
- Injury to solid organs (liver, spleen, kidney) is uncommon.
  - But can cause organs to tear off at points of attachment or subcapsular petechiae, contusions, lacerations or rupture.

Eye Injuries

- Up to 10% of blast survivors have significant eye injuries.
- Injuries not detected immediately may present months after an event.
- Symptoms: eye pain, irritation, altered vision, foreign body sensations, periorbital swelling, contusions.
- In rare cases, transient blindness, hyphema, and conjunctival hemorrhage may occur.

Shrapnel injury from RPG. The soldier continued fighting soon after treatment.

"Blast Injuries: Essential Facts." *Centers for Disease Control and Prevention.* September 11, 2006. http://www.bt.cdc.gov/masscasualties/blastessentials.asp

Ear Injuries

- The ear is the most frequently affected organ.
- Indications of injury are usually present at initial evaluation.
- Indications include: hearing loss, tinnitus, otalgia, vertigo, bleeding from external canal, TM rupture, mucopurulent otorhea.
- Anyone exposed to the blast should receive an otologic assessment and audiometry.

Combined Injuries

- Common combined injuries:
  - Blast and Burn
    - Fluid administration for adequate tissue perfusion without volume may be required for multiple injured patients with blast lung.
  - Blast and Crush
    - 20cc/kg bolus, continuous cardiac monitoring, and prepare to treat hyperkalemia pharmacologically.

Other Injury Considerations

- Concussions are common and often overlooked injuries.
- Compartment syndrome, rhabdomyolysis, and acute renal failure are associated with structural collapse, prolonged extrication, severe burns, and some poisonings.
- Grossly contaminated wounds are candidates for delayed closure.

"Blast Injuries: Essential Facts." *Centers for Disease Control and Prevention.* September 11, 2006. http://www.bt.cdc.gov/masscasualties/blastessentials.asp

Explosion Disaster Response

- On-site care
- On-site triage
- Treatment
- Collection of information

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Course Transcript

Slide 1: "Explosive Threats"
Welcome to the "Explosive Threats" tutorial designed by the Pacific Emergency Management, Preparedness and Response Information Network and Training Services at the University of Hawaii at Manoa.

Slide 2: "Explosive Threats: Bombings"
Recent events have made public health professionals far more concerned about potential terrorist threats. Preparedness has largely focused on weapons of mass destruction; however, the most common and most lethal terrorist tactic in recent history, the threat from explosive devices, is sometimes neglected. According to the Memorial Institute for the Prevention of Terrorism, 57% of all terrorist incidents since 1968 have been bombings, and these incidents have been responsible for 54% of terrorism-related fatalities during the same time period. The institute also reports that there have been at least 356 terrorist bombing incidents in the United States since 1968. Many of these incidents represent failed attacks, or attacks which did not cause casualties; however, terrorist bombings have caused 1,885 injuries and 192 fatalities in the U.S. Two of the most notable bombings in the United States were the 1995 Oklahoma City Bombing and the 1993 World Trade Center Bombing. On the morning of April 19, 1995, a massive truck bomb exploded at the Alfred P. Murrah Federal Building. The blast partially collapsed the 9-story structure, killing 167 and injuring 500. On February 26, 1993, members of Al Qaeda exploded a bomb in the parking garage of the World Trade Center. The blast killed 6 and injured 1042 people. Other, more recent incidents directed against other Western targets have included the Bali bombings, Khobar Towers Complex Blast, the Madrid 3/11 bombings, and the 2005 London bombings.

Slide 3: "Explosive Threats: Accidental & Industrial"
It is important to remember that explosive threats need not be the result of terrorism. Accidental or industrial explosions can also cause considerable damage. In Texas City, 1947, a cargo ship loaded with ammonium nitrate fertilizer caught fire. As firefighters and dock workers attempted to put out the blaze, two explosions occurred and the fire continued to spread. The incident caused approximately 600 deaths and 2,000 injuries. In 1985, a fire and rocket fuel explosion occurred at a processing plant in Henderson, Nevada. The blast destroyed the processing plant, killed 2, and injured approximately 300. Another non-combat incident occurred in 1986 when a 40,000-gallon JP-4 aviation fuel tank exploded at Osan Air Force Base in South Korea. The blast killed 14, including one American, and injured 12.

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Slide 4: "Types of Explosive Agents"

Explosives are divided into two types of agents that have the potential to be used by terrorists. High explosives, such as TNT and dynamite, detonate at speeds faster than the speed of sound. Such explosions generate an overpressure or blast wave with concurrent heat and gas. This effect is unique to high order explosives and does not occur with low explosives. Low explosives burn with slow velocity rather than detonate. Gunpowder is an example of a low explosive. Low explosives are generally the most common form of explosive agent used by terrorists.

Slide 5: "Bomb Threat Injury Model"

To better understand the impact of explosive agents on the public, the epidemiological triangle of host, agent and environment will be used to explain the Bomb Threat Injury Model. When examining the host, one factor to be considered is the general health status of victims. If an explosive device is detonated on the battle field, its potential victims would be roughly of the same health status due to the relative similarity of military combatants likely to be on the battlefield. If, however, detonation of a bomb occurs in a public area, one can expect to see a wide range of healthy as well as compromised individuals affected by the blast. Similarly, in a public place, there is also likely to be a wide variety of age groups and genders present and affected. Conversely, in combat, those affected would mostly be young and male. Psychologically, the range of people affected in a public place would be quite wide given the variation in people affected. Socioeconomic status is likely to also be a factor in psychological reactions as well as access to resources for dealing with the effects of the explosion. A final factor to consider would be the problems created by lack of access to immediate medical care. In civilian bombings, emergency medical personnel may have limited or no access to the site of the event, which in turn hampers prompt care. All these factors regarding the host need to be considered in the Bomb Threat Injury Model.

Slide 6: "Bomb Threat Injury Model"

The second point of the epidemiological triangle is the agent. Potential agents of injury include military ordnance and IEDs, which stands for improvised explosive devices. Military ordnance uses high explosives. It produces a predictable pattern of injury and uses advanced technology and targeted delivery systems to make its impact. In contrast, the IED, by its very nature is not predictable, since any material available to the device-maker is used in its construction. There is no sophisticated weaponry involved, and the bomber relies on human carriers to deliver the device. IEDs have become very familiar to the American public because of their extensive use by terrorist cells and suicide bombers in Iraq and Afghanistan. Once again, accidental explosions can also occur with varying effects depending on the agent involved.

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Slide 7: "Bomb Threat Injury Model"

The final part of the Bomb Threat Injury Model to be considered is the environment. Where the explosive device is detonated will determine the severity and type of injury sustained by bomb victims. Bombs detonated in an open space allow the blast wave to dissipate rapidly. On the other hand, open space allows for an increased number of injuries due to flying objects and shrapnel because of their ability to travel freely and widely. In a confined space, shock waves from the explosion will be amplified since there is no way to vent those waves. As a result, there will be more severe lung and gastrointestinal injuries in victims trapped in a confined space with an explosion. Finally, structural collapse occurs when the framework of a building is partially or completely destroyed. Injury patterns are similar to a confined space blast, along with fractures and crush injuries resulting from the collapse. Mass panic can often lead to stampede injuries when structural collapse occurs.

Slide 8: "At the Scene"

There are a number of special considerations that emergency responders and other medical personnel at the scene of an explosive event should take into account. First, it is important to remember that the blast site is a crime scene, and preserving evidence is an important consideration. Safety at the scene of an explosion is a critical issue. If an explosion was the result of a terrorist attack, there may be secondary devices designed to target first responders. Indicators of this may include: out-of-place packages, strange vehicles entering or leaving the scene, and undamaged or out-of-place vehicles. There is also the potential for perpetrators to still be at the scene as observers, triggermen for secondary attacks, or even as patients. Exposure to inhaled toxins such as CO, CN, and MetHgb must be considered in industrial and terrorist explosions. Other biological and chemical warfare agents may also be delivered via explosive devices. The scene may also contain significant amounts of shrapnel. Finally, many explosive events also bring the risk of building collapse.

Slide 9: "Personal Protective Equipment"

The Centers for Disease Control and Prevention list the following as appropriate personal protective equipment for explosive events: coveralls, heavy coat, heavy gloves, steel-toed boots, hard hat, eye protection, dust particle mask, and a breathing apparatus for toxic fumes.

Slide 10: "Triage"

Terrorist bombings often leave large numbers of non-critically injured patients. Studies report that approximately 20% of those involved will have critical injuries. As a result, overtriage may harm the treatment of the smaller number of patients with urgent and salvageable injuries. Furthermore, studies find that up to 75% of victims at an event may self-refer to a hospital and will need to be triaged prior to receiving care. Therefore, hospitals must be prepared to decontaminate and triage large numbers of self-referral patients.

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Slide 11: "Types of Blast Injury"

Blast injuries are often categorized into four different types of injury. The first type of blast injury is known as primary blast injury. It is caused by the effect of the blast wave on the body, which affects primarily the gas-filled organs as a result of extreme pressure differentials developed at body surfaces. Organs most susceptible include the middle ear, lung, and bowel. Secondary blast injuries are caused by flying debris and fragments propelled by an explosion's blast winds. Penetrating injury to the body can occur, and at very close distances, limb amputation or total body disruption may occur. Some explosive devices may contain nails or other forms of shrapnel to maximize secondary injuries. Clothing often provides some protection, and injuries to the extremities, head, and neck predominate. Eye injuries are also likely during an explosion. Tertiary injuries occur when a person is thrown against a stationary object by the force of the explosion. This may result in multiple injuries including blunt trauma and bone fractures. Quaternary blast injuries define the remainder of the injuries suffered as a result of an explosion. These injuries include crush injuries suffered from collapsing structures, inhalation of toxic gasses and debris, thermal burns, exposure to radiation, and exacerbation of prior medical conditions.

Slide 12: "Blast Lung"

Blast lung is the most common fatal injury among initial survivors of an explosion. Blast lung is caused by the blast wave of a high explosive device and is a unique effect caused by these devices. The blast wave causes tearing, hemorrhage, contusion, and edema with resultant ventilation-perfusion mismatch. According to the Centers for Disease Control, blast lung is a clinical diagnosis and is characterized by respiratory difficulty and hypoxia, which can occur without any obvious external injuries to the chest. Clinical symptoms of blast lung may include dyspnea, hemoptysis, cough, and chest pain. Signs may include tachypnea, hypoxia, cyanosis, apnea, wheezing, decreased breath sounds, and hemodynamic instability. The associated pathology of blast lung may include bronchopleural fistula, air emboli, and hemothoraces or pneumothoraces.

Slide 13: "Blast Lung: Diagnostic Evaluation"

The CDC recommends that a chest radiograph be performed on anyone exposed to the blast. Blast lung tends to be more common among patients with skull fractures, greater than 10% body surface area burns, or penetrating injury to the head or torso. Furthermore, it is important to recall that higher incidences of blast lung occur in confined spaces, making it important to note a patient's location at the time of the explosion. A characteristic butterfly pattern of lung injury may be revealed by the x-ray. Other methods of evaluation may include: arterial blood gases, computerized tomography, and doppler technology. Often, diagnosis and management of patients with severe blast lung is challenging because it is frequently accompanied by shock and unconsciousness.

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Slide 14: "Blast Lung: Management"

Initial triage, resuscitation, treatment, and transfer should follow standard protocols; however, it should be noted that prophylactic chest tube, or thoracostomy, is recommended by the CDC before general anesthesia or air transport. Patients with confirmed or suspected blast lung should also receive supplemental oxygen flow to prevent hypoxemia via NRB mask, CPAP, or ET tube. Impending airway compromise, secondary edema, injury, or massive hemoptysis all require immediate intervention to secure the airway, and patients with massive hemoptysis or significant air leaks may benefit from selective bronchus intubation. Also, clinical evidence of hemothorax or pneumothorax warrants decompression. If ventilatory failure occurs or is eminent, patients should be intubated. However, mechanical ventilation and positive pressure may increase the risk of alveolar rupture, pneumothorax, and air embolism and therefore, prevention of intubation and positive pressure ventilation is recommended. Finally, if air embolism is suspected, high oxygen flow should be administered and the patient should be positioned in a prone, semi-left lateral, or left lateral position making it more difficult for air bubbles to enter the left ventricle. Positioning is often complicated by other injuries and the security of the airway.

Slide 15: "Abdominal Injuries"

Once again, significant injuries may be found in gas-containing structures of the abdomen, particularly in the colon, due to the blast wave's effects at the tissue-gas interface. Abdominal injuries can occur even if no external injuries are visible. It is important to remember that perforations can be delayed 24-48 hours after a blast. Presentation of these injuries may include: bowel perforation, hemorrhage in the form of small petechiae to large hematomas, mesenteric shear injuries, solid organ lacerations, or testicular rupture. Abdominal injuries should be suspected in anyone with abdominal pain, nausea, vomiting, hematemesis, rectal pain, tenesmus, testicular pain, or unexplained hypovolemia. Solid organs, such as the liver, spleen, and kidney, typically remain undamaged during the primary effects of a blast. However, these organs are more likely to be injured by secondary or tertiary effects. The blast wave can generate shear forces at points of attachment of organs or at the surfaces of organs. This can cause an organ to tear off at its point of attachment or, in the latter case, can cause subcapsular petechiae, contusions, lacerations or rupture.

Slide 16: "Eye Injuries"

Up to 10% of all blast survivors have significant eye injuries. These injuries can present days, weeks, or even months after an event. Therefore, the Centers for Disease Control encourage liberal referral for ophthalmologic screening. Symptoms can include eye pain or irritation, altered vision, foreign body sensations, periorbital swelling or contusions. In rare cases, transient blindness as well as hyphema, and conjunctival hemorrhage may occur as a result of the blast wave; however, perforation and other trauma is far more likely.

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Slide 17: "Ear Injuries"

The ear is the organ most frequently affected during an explosion. The blast wave can overwhelm the fragile structures of the ear causing tympanic membrane rupture, fracture or dislocation of the ossicles, or permanent inner ear damage. In general, the ear most exposed to the blast will suffer the most severe damage. Indications of ear injury are usually present at the time of the initial evaluation. Indications of ear injury include: hearing loss, tinnitus, otalgia, vertigo, bleeding from the external canal, TM rupture, or mucopurulent otorhea. Anyone exposed to the blast should receive an otologic assessment and audiometry. Tympanic membrane perforation is the most common aural injury and will generally heal without intervention unless infected.

Slide 18: "Combined Injuries"

Combined injuries are common during explosive events, particularly blast and burn or blast and crush injuries. Considering all aspects of a combined injury is critical. In all cases, airway management and ventilation are essential to survival and should be achieved with standard techniques. In combined burn and blast injuries, the burn injury will require significant amounts of fluid resuscitation; however, care should be taken to avoid fluid overload, which may increase the risk of adult respiratory distress syndrome (ARDS). In the field, fluid resuscitation should be targeted to vital signs to avoid hypotension, and boluses should be given only as necessary to achieve this. In blast/crush injuries, IV fluid boluses will be necessary to reduce the danger of hyperkalemic cardiac arrest on release of the entrapped tissue. In the field, standard 20 cc/kg bolus, or about 2 L in an adult, will offer some protection; however, continuous cardiac monitoring should be established as soon as possible and preparations should be made to treat hyperkalemia pharmacologically with calcium and insulin. Dialysis may also be necessary to treat electrolyte abnormalities or renal failure due to tissue destruction leading to myoglobinuria.

Slide 19: "Other Injury Considerations"

The following is a final list of miscellaneous considerations offered by the CDC which do not fall neatly into any category. First, it is important to remember that concussions are common and easily overlooked injuries in explosive events. Often symptoms of concussion may be similar to post-traumatic stress disorder. The blast wave can sometime cause concussions or mild traumatic brain injury even without a direct blow to the head. Compartment syndrome, rhabdomyolysis, and acute renal failure are associated with structural collapse, prolonged extrication, severe burns, and some poisonings. Finally, it should be noted that grossly contaminated wounds are candidates for delayed closure.

Slide 20: "Explosion Disaster Response"

Responders and public health officials need to be familiar with disaster plans prior to an actual event. There are four components to explosion disaster response. The first component is on-site care. Once the site is deemed secure for responders to enter, victim treatment, transportation, and communication with

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hospitals can begin. In order to evenly distribute medical care among the injured, an off-site triage center should be set up. It should be safely away from the site, yet accessible to hospitals and clinics. Immediate treatment should include stabilization, control of bleeding, treatment of wounds and splinting of fractures. Victims should be checked for all types of contamination such as chemical, biological, or radiological contamination. Emotional and psychological injuries should not be overlooked, although life-threatening injuries should be addressed first. However, counseling for both victims and responders should be made available. Finally, information from blast victims can aid in future emergency planning, reunion with family members, and the investigation of the incident, particularly if it is a criminal act. These four components are essential to mounting an efficient response in the event of an explosion.

Slide 21: "Sources"
The following sources were consulted during the development of this course.

Slide 22: "Sources"
Development of this tutorial was assisted, in part, by subject matter experts Ray Swienton, MD, Italo Subbarao, MD, and Tom Lehman.

Slide 23: "Pacific EMPRINTS"
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