Bombings: Injury Patterns and Care

Blast Injuries Module Curriculum Guide

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American Medical Association (AMA)
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A task force was established with representative experts from emergency medicine including physicians, surgeons, nurses, and EMS. Core competencies and knowledge objectives were developed using a consensus approach. A writing group then developed teaching objectives and course content based on the core competencies.

The *Bombings: Injury Patterns and Care* curriculum is designed to be the minimum content that should be included in any all-hazards disaster response training program. This content is designed to update the student with the latest clinical information regarding blast related injuries from terrorism.

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CONTENT DESIGN

This content covers eight main topic areas designed to educate emergency medical personnel in the assessment and initial management of patients who are injured during an explosive event. The content builds on existing knowledge developed in HAZMAT and WMD training courses and is designed to be integrated into courses and other training experiences using an all-hazards approach. The emphasis for each topic is the unique characteristics of an explosive event, such as a terrorist bombing, that results in mass casualties.

The content for each topic is accompanied by slides. A few teaching tips are provided in the Curriculum Guide.

CONTENT TOPICS

- Background (Explosives and Terrorist Bombings)
- Scene Safety
- Triage
- Blast Injuries
- Crush Injuries and Compartment Syndrome
- Military Experience
- Special Considerations
- Psychological Issues

TARGET AUDIENCE

- Emergency physicians
- Emergency nurses
- Emergency medical service personnel
- Other healthcare personnel who would be involved in a mass casualty event

GOALS

In general, the goal of this content is to cover the unique knowledge and skills required to effectively respond to a mass casualty explosive or bombing event. The content can be integrated into existing materials or taught as a stand-alone course. The content includes: (1) the uniqueness of blast injury, including blast physics, (2) the most common types of blast injuries, and (3) the appropriate treatment (prehospital and initial hospital) for injures that result from blasts.

Teaching Tips

These topics can be most successfully taught using real-life scenarios, cases, and examples to facilitate an interactive instructional strategy—one that focuses on active learning. Active learning requires that learners are involved in the learning process.

To provide an active learning environment, learners must interact or become involved with realistic situations and knowledge. By incorporating techniques that encourage participants to discuss, question, and clarify, instructors can increase retention and encourage the use of problem solving skills.

TIME REQUIREMENTS

The basic content can be completed in approximately three hours. However, the topics are designed for flexibility and can be adapted to presentations that vary in length by increasing or decreasing the amount of detail and the level of learner interaction.

For a 3-hour session, the following times are suggested:

▪ Background	10 minutes
▪ Explosive Events	10 minutes
▪ Blast Injuries	40 minutes
▪ Crush Injuries	30 minutes
▪ Military Experiences	10 minutes
▪ Special Considerations	10 minutes
▪ Psychological Issues	10 minutes
▪ Patient Cases	60 minutes

LEARNING OBJECTIVES

The following learning objectives cover all of the content. They are intended as a blueprint for what learners should know after the content has been taught. (There are no learning objectives for the background content.)

Scene Safety

1. Describe common hazards that could be encountered in an explosive event.
2. Recognize the personal protective equipment (PPE) appropriate for use during explosive events.

Triage

3. List the factors common to explosive events that may complicate effective triage.
4. Explain the possible effect of overtriage at explosive events.
5. Explain the issues related to patient self-referral in explosive events.

Blast Injuries

6. Describe the unique aspects of blast injury, including blast physics and the pattern of injuries.
7. List the factors affecting severity (morbidity and mortality) of injuries in an explosive event.
8. Explain the pathophysiology of blast injuries.
9. Define the four categories of blast injuries.
10. List the most common types of injuries in each category—primary, secondary, tertiary, and quaternary (miscellaneous).

Primary Blast Lung Injury

11. Describe the pathophysiology of blast lung.
12. Describe the clinical manifestations of blast lung injury.
13. Explain the appropriate treatment (prehospital and initial hospital) for blast lung injury.
14. Explain why tympanic membrane rupture may or may not be an indicator for blast lung injury.

Additional Primary Blast Injuries

15. Describe the presentation and clinical manifestations of other primary blast injuries, including ear, abdominal, and head injuries.
16. Explain the appropriate treatment (prehospital and initial hospital) for other primary blast injuries, including ear, abdominal, and head injuries.

	17. Explain the treatment priorities (prehospital and initial hospital) for combined injuries, including blast lung injury and burn injury; blast lung injury and crush injury.
Military Experiences	18. Discuss current military experiences in blast injury care, such as hemorrhage control and use of tourniquets.
Special Considerations	19. Describe the considerations that should be addressed for special needs patients such as children, women who are pregnant, the elderly, the disabled, and those with language barriers.
Psychological Issues	20. Describe factors that affect mental health during an explosive event.

BACKGROUND INFORMATION: EXPLOSIVES AND TERRORIST BOMBINGS

This topic provides a brief history of recent explosions and bombings used by terrorists. The types of explosives used, the characteristics of explosives, and explosive classification are also included. There are no specific learning objectives related to this topic, since it is designed to provide background and context to the subsequent topics.

Explosive devices are a rather inexpensive and easy method for terrorists to trigger major disruptions to our everyday lives. Terrorists have used everything from a small backpack to large trucks and even commercial jet airliners to deliver the explosive agent. Injuries can vary from various forms of trauma and burns to amputations or even immediate death.

Even though an all-hazards approach is used, the content covered in this curriculum is focused on terrorist events that result in mass casualties. Most disaster training experiences cover the definition and types of terrorism. This information is included here as a review, if it is needed.

Key Elements of Terrorism

Terrorism can be defined as containing four key elements.

1. It is premeditated—planned in advance, rather than an impulsive act of rage.
2. It is political—not criminal but designed to change the existing political order.
3. It is aimed at civilians—not at military targets or combat ready troops.
4. It is carried out by sub-national groups—not by the army of a country.

Types of Terrorism

Nationalist terrorism—seeks to form a separate state for their own national group. These terrorists use violence to capture national attention and to alienate those not supporting their movement. Examples include the Irish Republican Army (IRA), Palestine Liberation Organization (PLO), and Kurdistan Workers' Party (KWP).

Religious terrorism—uses violence to further their purpose targeting broad categories of enemies. Religious terrorists come from major faiths as well as small cults. The more extreme sects use an almost limitless amount of violence against anyone who is not part of their religious group, and they are considered some of the most dangerous terrorists. Nearly half of the 56 known international terrorist groups are religiously motivated. Examples include Osama bin Laden's al-Qaeda network and the Aum Shinrikyo doomsday cult in Japan.

State-sponsored terrorism—use of terrorist groups or surrogate warriors by radical states as a foreign policy tool. With enhanced state funded resources at their disposal, they are often able to carry out larger and more deadly attacks including commercial airliner bombings. One example is the Iranian government sponsorship of young militants to seize the American embassy in Tehran in 1979.

Suicide terrorism—used throughout history but it has become much more common in the last 20 years. Both religious and secular terrorist groups use

this form of terrorism. Some feel suicide terrorists are crazy, but many experts say such terrorists are just deeply committed to their cause and see themselves as martyrs who can inspire imitation.

These types of terrorism are not mutually exclusive. For example, terrorism that is achieved through suicide bombings is often both religiously and nationalistically motivated.

Recent Terrorist Explosive Events

Mumbai bombing, India July 11, 2006 – Seven bombs were placed on commuter trains during rush hour. 209 were killed and over 700 were injured.

Tel Aviv, Israel, January 19, 2006—A suicide bomber in a small fast food restaurant killed himself and wounded 20 others. Most customers were outside the restaurant, but the bomber went inside and detonated the bomb.

Iraq hotel bombing, Baghdad, October 24, 2005—Three car bombs were detonated at the Palestine and Sheraton hotels. Six people were killed and 15 others were wounded.

London Subway Bombing, July 11, 2005—Three bombs on the underground trains and one bomb on a bus killed 56 (including the 4 terrorists) and injured over 700; 350 required hospital treatment; 22 were admitted in serious or critical condition.

Madrid Train Bombing, March 11, 2004—Ten bombs exploded in 4 commuter trains, killing 177 instantly and injuring more than 2000. Fourteen people died later. Total casualties were 191 people.

World Trade Center, September 11, 2001—Total dead and missing 2,992; 2749 in New York, 184 at the Pentagon, 40 in Pennsylvania, and 19 hijackers.

Tel Aviv Disco, June 1, 2001—A suicide bomber killed 20 and injured 120. The terrorist mingled with a large group of teenagers, who were standing in line to enter a disco. While still in line, he detonated the explosives strapped to his body. The explosive charge contained a large number of metal objects, including balls and screws, designed to increase the extent of injuries.

*Centennial Olympic Park, Atlanta, GA***,** July 27, 1996—A shrapnel-laden pipe bomb hidden in a backpack exploded during the Summer Olympics. Two people were killed and 111 were injured.

Murrah Federal Building, Oklahoma City, OK, April 19, 1995—A rented truck containing about 5,000 pounds (2,300 kg) of explosive material exploded killing 168 people, including one person who died in the rescue effort. Over 800 people were wounded. The bomb was composed of ammonium nitrate (an agricultural fertilizer) and nitromethane (a highly volatile motor-racing fuel) in a mixture also known as ANFO (ammonium nitrate/fuel oil) or Kinepak.

World Trade Center, February 26, 1993—A car bomb exploded in a basement

garage, killing 6 and injuring 1040 others. The complex 1300 lb (600 kg) bomb was made of urea pellets, nitroglycerin, sulfuric acid, aluminum azide, magnesium azide, and bottled hydrogen. Sodium cyanide had been added to the mix so that the vapors could go through the ventilation shafts and elevators of the towers.

*Pan Am 103, Lockerbie, Scotland***,** December 21, 1988—A terrorist bomb exploded in flight killing 259 passengers and 11 people who were on the ground. Twelve to 16 oz (340 to 450 g) of plastic explosive was detonated in the plane's forward cargo hold, triggering a sequence of events that led to rapid destruction of the aircraft.

Unabomber **(**Theodore John Kaczynski, PhD) – The Unabomber was convicted of murder for sending mail bombs to various people over almost 18 years from the late 1970's through the early 1990's. His bombs killed three and wounded 29. He justified his crimes as a fight against the evils of technological progress.

Types of Explosives

Car and truck bombs are very powerful weapons in the terrorist's arsenal, especially for suicide attacks. Terrorists also employ letter and parcel bombs, explosive and incendiary bombs, and a few groups are known to possess either rocket-propelled grenades (RPGs) or surface-to-air shoulder-fired missiles that can bring down civilian or military aircraft.

Improvised explosive devices

Improvised explosive devices (IEDs) are handmade or improvised bombs used by terrorists. They can be made from stolen explosives, commercial blasting supplies or fertilizer, fuel oil, and other household ingredients.

Examples of IEDs:

Pipe Bomb
This is the most common type of terrorist bomb and usually consists of low-velocity explosives inside a tightly capped piece of pipe. Pipe bombs are very easily made using gunpowder, iron, steel, aluminum, or copper pipes. They are sometimes wrapped with nails to cause more harm.

Molotov Cocktail
This improvised weapon is used by terrorists world-wide. Molotov cocktails are extremely simple to make and can cause considerable damage. They are usually made from materials such as gasoline, diesel fuel, kerosene, ethyl or methyl alcohol, lighter fluid, and turpentine, all of which are easily obtained. The explosive material is placed in a glass bottle, which breaks upon impact. A piece of cotton serves as a fuse, which is ignited before the bottle is thrown at the target.

Fertilizer Bomb
Fertilizer bombs consist of ammonium nitrate. Hundreds of kilograms may be required to cause major damage. The Irish Republican Army, Tamil Tigers, and some Middle Eastern groups use the ammonium nitrate bomb. This type bomb was used in the Oklahoma City bombing.

Barometric Bomb
The barometric bomb is one of the more advanced weapons in the terrorist's arsenal. The detonator of the bomb is linked to an altitude meter, causing the explosion to occur during flight.

Fuel-air explosives

Also called high-impulse thermobaric weapons (HITs) and enhanced blast explosives, fuel-air explosives use atmospheric oxygen, instead of carrying an oxidizer in their explosives. They produce more explosive energy for a given size than do other explosives.

"Dirty" bombs

The term **dirty bomb** is used to refer to a Radiological Dispersal Device (RDD), a radiological weapon that combines radioactive material with conventional explosives. A dirty bomb kills or injures through the initial blast of the conventional explosive and spreads airborne radiation and contamination.

Incendiary bombs

Also known as fire bombs, incendiary bombs are designed to start fires or destroy sensitive equipment using materials such as napalm, thermite, chlorine trifluoride, or white phosphorus.

Military munitions

Military munitions are ammunition products and components produced for or used by the armed forces. They include explosives, pyrotechnics, riot control agents, smokes and incendiaries, bulk explosives, rockets, guided and ballistic missiles, bombs, warheads, mortar rounds, artillery ammunition, small arms ammunition, grenades, mines, torpedoes, depth charges, cluster munitions, dispensers, and demolition charges.

Classification of Explosives

Explosives are categorized as high-order explosives (HE) or low-order explosives (LE).

HE produces a defining supersonic over-pressurization shock wave. Examples of HE include TNT, C-4, Semtex, nitroglycerin, dynamite, and ammonium nitrate fuel oil (ANFO).

LE creates a subsonic explosion and lack HE's over-pressurization wave. Examples of LE include pipe bombs, gunpowder, and most pure petroleum-based bombs such as Molotov cocktails or aircraft improvised as guided missiles.

HE and LE cause different injury patterns due to the presence or absence of the over-pressurization wave.

Explosive and incendiary (fire) bombs are further characterized based on their source. "Manufactured" implies standard military-issued, mass produced, and quality-tested weapons. "Improvised" describes weapons produced in small quantities, or use of a device outside its intended purpose, such as converting a commercial aircraft into a guided missile. Manufactured (military) explosive weapons are exclusively HE-based. Terrorists will use whatever is available – illegally obtained manufactured weapons or

improvised explosive devices (IED) that may be composed of HE, LE, or both.

Manufactured and improvised bombs cause markedly different injuries.

Blast wave refers to the intense over-pressurization impulse created by a detonated HE. Blast injuries are characterized by anatomical and physiological changes from the direct or reflective over-pressurization force impacting the body's surface. The HE "blast wave" (over-pressure component) should be distinguished from "blast wind" (forced super-heated air flow). Blast wind may be encountered with both HE and LE.

BACKGROUND INFORMATION: CRIMINAL INVESTIGATION AND EVIDENCE PRESERVATION

The entire scene at an explosive event is considered a crime scene and preserving evidence is important. The principles of criminal investigation and evidence preservation should guide responders.

Be aware of:

- Indicators of a crime scene
- Evidence preservation and chain of custody
  - Avoid disturbing or compromising evidence
- Possible suspects or perpetrators

SCENE SAFETY

Objective

1. Describe common hazards that could be encountered in an explosive event.

Common Hazards

- secondary devices
- possible places for secondary devices
- shrapnel
- building collapse/structural damage
- air-borne contaminants
- contaminated patients and scene/environment
- terrorists as patients

Teaching Tip

Use examples from previous events to teach these hazards.

Objective

2. Recognize the personal protective equipment (PPE) appropriate for use during explosive events.

PPE for Explosive Events

- Coveralls
- heavy coat
- heavy gloves
- steel-toed boots
- hard hat
- eye protection
- dust particle mask
- breathing apparatus for toxic fumes

TRIAGE

Objective

3. *List the factors common to explosive events that may complicate effective triage.*

Factors Complicating Effective Triage

- Severe internal injuries caused by the blast wave may not be initially apparent during triage.
- In most victims, death from explosive events is the aftermath of combined blast, ballistic, and thermal effect injuries.
- Terrorist bombs often contain nails, bolts, and other sharp objects that produce unique injury patterns.
- Bombs or explosive devices are often detonated in enclosed spaces such as buses or buildings, resulting in an increase in the effects of the pressure wave.

Objective

4. Explain the possible effects of overtriage at explosive events.

Overtriage

Terrorist bombing events usually result in large numbers of patients who are not critically injured. Studies report around 20% of those involved have critical injuries. This causes medical resources to be overwhelmed when they are faced with hundreds of patients who do not need immediate attention. This overtriage may delay recognition and treatment of the smaller numbers of patients with urgent and salvageable life threatening injuries.

Accurate and efficient triage is extremely important. Mortality of critically injured patients may be related to the level of overtriage.

Objective

5. Explain the issues related to patient self-referral in explosive events.

Patient Self-referral

Up to seventy-five per cent of victims at a blast event will self-refer to a hospital, arriving by private transportation. These patients may need decontamination and will need to be triaged prior to receiving care. Hospitals need to be prepared to decontaminate and triage large numbers of patients who arrive on their own.

Teaching Tip

This is a place where data from real events is important. Information from events in Israel could be used to help learners understand the impact of self-referred patients.

BLAST INJURIES

Objective

6. *Describe the unique aspects of blast injury, including blast physics and pattern of injuries.*

Explosions from terrorist bombs can produce unique and unusual patterns of injury. These can even be unique when compared to military-type wounds encountered on the battlefield. Bombs often inflict multi-system injuries on large groups of people simultaneously, causing many life-threatening injuries.

Blast Physics

Blast injuries are the result of the rapid chemical conversion of a solid or

liquid into highly pressurized gasses that expand rapidly and compress the surrounding air. This generates a pressure pulse, which spreads as a blast wave in all directions.

The effects of the blast wave are more intense in a confined space like a building or bus. The shock wave is amplified as it is reflected off walls, floors, and the ceiling. If the blast occurs outside, the blast wave will dissipate rapidly.

Example: Murrah Federal Building, Oklahoma City, OK, 1983
(See graphic in slide presentation.)

Pattern of injuries

The injury patterns related to explosive events depend on variables such as the environmental setting, amount of explosives, and type of device used. Blast injuries should be suspected no matter how far a patient was from the center of the blast.

In the 1983 bombing in Beirut, there were 346 casualties—234 (68%) were killed immediately. Among the 85 survivors, there were 62 soft tissue injuries, 43 bone fractures, 37 head injuries (4 deaths), 15 chest trauma (2 deaths), 5 burns (2 deaths) 5 abdominal trauma, 5 eye injuries, and 9 peripheral nerve injuries (Lee, *Survey of Terrorist Bombing Tactics and How They Influence Patterns of Injury*).

Among the 83 patients hospitalized after the 1995 Oklahoma City bombing, 98% suffered soft tissue injuries, 24% had severe lacerations, 57% were treated for fractures or dislocations, 53% were treated for head injuries, 37% had eye injuries, and 11% were treated for burns. For the people who were treated and released from emergency departments, 88% had soft tissue injuries and 15% were treated for head injuries, 11% had eye injuries, and 8% had fractures or dislocations (Shariate, Mallonee, and Stidham, *Summary of Reportable Injuries in Oklahoma: Oklahoma City Bombing Injuries*).

Most injuries are non-critical soft tissue and skeletal. Head injury accounts for approximately 50-70% of the deaths. However, most head injuries are non-critical (98.5%). Most blast lung injuries cause immediate death.

Most types of injuries occur in bombing events. Injuries include primary blast injuries (pulmonary, auditory, and abdominal), serious penetrating injuries (abdominal and vascular) solid abdominal organ injuries (liver or spleen), and serious intracranial injuries (open or depressed skull fractures, intracranial hemorrhage). In bombing incidents that include structural collapse, patients may experience inhalation injuries, crush injuries, and fractures. In bombings that occur in confined spaces, there is a higher incidence of pneumothorax, blast lung injury, tympanic membrane rupture, as well as burns, and hepatic or splenic injury. In open air explosive events, the predominant injury is penetrating soft tissue injuries caused by shrapnel. (Arnold, Halpern, Tsai, and Smithline, *Mass Casualty Terrorist Bombings: A Comparison of Outcomes by Bombing Type*).

Objective

7. List the factors affecting the severity (morbidity and mortality) of injuries in an explosive event.

Factors Affecting Severity

- magnitude of the blast
- composition of the explosive e.g., presence of shrapnel or other material that can be propelled, radiological or biological contamination
- environment of the blast— open space vs. closed space, underwater, urban, existence of protective barriers
- distance between the victim and the blast
- structural collapse
- triage accuracy
- available medical resources
- triage efficiency

Objective

8. Explain the pathophysiology of blast injuries.

Pathophysiology of Blast Injuries

The shock waves from a blast are believed to affect tissues and organs in a number of different ways. These four proposed mechanisms are believed to have the following impacts*:

- *spalling*—caused by a shock wave moving between tissues of different densities as in the lungs or internal organs.
- *implosion*—caused by entrapped gasses contained in hollow organs compressing then expanding causing them to rupture.
- *shearing*—this is caused when tissues with different densities respond by moving at different speeds
- *irreversible work* – caused by forces exceeding the tensile strength of the tissue.

*Spalling, implosion and shearing are thought to be three mechanisms that cause blast injuries. Irreversible work is currently being researched as a more likely mechanism of injury.

Objective

9. *Define the four categories of blast injuries.*

Categories of Blast Injuries

Primary blast—unique to high-order explosives; results from the impact of the over-pressurization wave with body surfaces.

Secondary blast—results from flying debris and bomb fragments.

Tertiary blast—results from individuals being thrown by the blast wind.

Quaternary blast—all explosion-related injuries, illnesses, or diseases not due to primary, secondary, or tertiary mechanisms—includes exacerbation or complications of existing conditions.

Objective

10. *List the most common types of injuries in each category—primary, secondary, tertiary, and quaternary (miscellaneous).*

Common Primary Blast Injuries

The most common primary blast injuries include:

- blast lung—pulmonary barotraumas
- head—traumatic brain injury (TBI), concussion
- ear—tympanic membrane (eardrum) rupture
- ear—middle ear damage
- abdomen—hemorrhage
- abdomen—organ perforation

Common Secondary Injuries

The most common cause of death in a blast event is secondary blast injuries. These injuries are caused by flying debris generated by the explosion. Terrorists often add screws, nails, and other sharp objects to bombs to increase injuries.

The most common types of secondary blast injuries are:

- trauma to the head, neck, chest, abdomen, and extremities in the form of penetrating and blunt trauma
- fractures
- traumatic amputations
- soft tissue injuries

Treatment for most secondary blast injuries follows established protocols for that specific injury.

Common Tertiary Injuries

Tertiary injuries result from individuals being thrown by the blast wind.

The most common types of tertiary blast injuries are head injuries, skull fractures, and bone fractures.

Treatment for most tertiary blast injuries follows established protocols for that specific injury.

Common Quaternary Injuries

All explosion-related injuries, illnesses, or diseases not due to primary, secondary, or tertiary mechanisms are considered quaternary blast injuries. This includes exacerbation or complications of existing conditions.

The most common quaternary blast injuries include:

- burns
- head injuries
- asthma
- COPD
- other breathing problems
- angina
- hyperglycemia
- hypertension
- crush injuries

Treatment for most quaternary (miscellaneous) injuries follows established

protocols for that specific injury. (Crush injuries are discussed after blast lung injury and other blast injuries in this curriculum guide.)

Primary Blast Lung Injury

Blast lung injury is a major cause of morbidity and mortality among blast victims both at the scene and at the hospital among initial survivors. Symptoms are usually present at the time of evaluation, but can have an onset several hours after the explosion.

Teaching Tip

Insert a patient case(s) here—with a story that connects to a blast scenario, include typical signs and pathophysiology. Then involve the participants in determining what to do, including both prehospital and initial hospital treatment.

Objective

11. Describe the pathophysiology of blast lung.

Blast Lung: Pathophysiology

The impact of the blast wave results in tearing, hemorrhage and edema of lung tissue. Examination of the lungs show ecchymoses, petechiae, lacerations, and increased weight due to edema and hemorrhage. There is also damage to airway epithelium and intraalveolar septa. These pathological changes result in ventilation-perfusion mismatch and the potential for air embolism.

Objective

12. Describe the clinical manifestations of blast lung injury.

Blast Lung: Clinical Manifestations

- Tachypnea
- Hypoxia
- Cyanosis
- Apnea
- Wheezing
- Decreased breath sounds
- Hemoptysis
- Cough
- Chest pain
- Dyspnea
- Hemodynamic instability

Objective

13. Explain the appropriate treatment (prehospital and initial hospital) for blast lung injury.

Blast Lung: Treatment

Patients should receive high flow oxygen sufficient to prevent hypoxemia via non-rebreather mask, CPAP, or endotracheal intubation. Fluid administration is similar to that of pulmonary contusion, providing enough fluid to ensure tissue perfusion but restricting the amount to avoid volume overload. Impending airway compromise, secondary pulmonary edema, or massive hemoptysis requires intervention to secure the airway. Consider selective bronchus intubation for severe hemoptysis or significant air leaks. Hemo- or pneumothorax warrants prompt decompression. If ventilatory failure occurs, the patient should be endotracheally intubated, but caution must be exercised to prevent alveolar rupture or air embolism due to positive pressure ventilation. Patients with air embolism should be positioned in prone, semi-

left lateral, or left lateral positions and transferred to a hyperbaric chamber.

There are no definitive guidelines for observation, admission, or discharge following evaluation of patients in the emergency department. Patients with blast lung injury may require complex management and admission to an ICU. Observation is recommended for patients with complaints or findings suggestive of blast lung. Discharge decisions depend upon associated injuries. Patients with normal chest radiographs and ABGs who have no complaints that would suggest blast lung can be considered for discharge after 4-6 hours of observation.

Objective *14. Explain why tympanic membrane rupture may or may not be an indicator for blast lung.*

Tympanic Membrane Rupture

Tympanic membrane rupture indicates exposure to an over pressurization wave. It may be found in victims with severe pulmonary, intestinal, or other injuries, or it may be found in isolation. Its presence does not indicate that more sinister blast injuries exist.

Patients from an explosive event who arrive at a medical facility should be evaluated and resuscitated per standing protocols. All patients should have a secondary evaluation and examination to identify all blast-related injuries including perforated tympanic membranes. Remember, serious blast injuries can occur in the absence or presence of tympanic membrane rupture.

Although no strict guidelines exist, stable patients without signs and symptoms suggestive of clinically significant blast injury, may likely be discharged after 4 to 6 hours of observation despite the presence of TM rupture.

In the Madrid, Spain bombing, TM rupture was reported in 99 of 243 patients; of 17 critically ill patients with pulmonary injuries from the blast, 13 had ruptured TMs, 4 did not. Ruptures also occurred in 18 of 27 critically injured patients (DePalma, Burris, Champion, Hadgson, *Blast Injuries*, NEJM).

Objective 15. *Describe the presentation and clinical manifestations of other primary blast injuries, including ear, abdominal, and head injuries.*

Ear Injuries

Ear injuries may include not only TM rupture, but also ossicular disruption, cochlear damage, and foreign bodies.

Abdominal Injuries

Abdominal injuries (also called blast abdomen) include abdominal hemorrhage and abdominal organ perforation.

Clinical manifestations include:
- abdominal or testicular pain
- tenesmus
- rectal bleeding
- solid organ lacerations
- rebound tenderness

- guarding
- absent bowel sounds
- signs of hypovolemia
- nausea
- vomiting

Head Injuries

Primary blast waves can cause concussions or mild traumatic brain injury (MTBI) without a direct blow to the head. Consider the proximity of the victim to the blast particularly when given complaints of loss of consciousness, headache, fatigue, poor concentration, lethargy, amnesia, or other constitutional symptoms. The symptoms of concussion and post traumatic stress disorder (PTSD) can be similar.

Teaching Tip

Continue the use of the patient cases here to demonstrate treatment.

Objective

16. Explain the appropriate treatment (prehospital and initial hospital) for other primary blast injuries including ear, abdominal, and head injuries.

Treatment

Treatment for most injuries from primary blast should follow established protocols for that specific injury.

Treatment: Ear Injuries

For ear injuries, no intervention is required immediately, but patients should be evaluated within 24 hours. Spontaneous healing occurs in 50-80% of all patients with perforations. Foreign bodies or debris in the external auditory canal can be removed by suction under a microscope.

Treatment: Abdominal Injuries

Treatment for abdominal injuries follows established protocols. It is important to recognize that perforations can be delayed and develop 24 to 48 hours after the blast. There is the possibility of missed injury, especially in semiconscious or unconscious patients. Manifestations of peritonitis can occur hours or days after a blast.

Treatment: Head Injuries

For head injuries, treatment follows established protocols, but it is important to remember that these injuries may be easily missed.

Objective

17. *Explain the treatment priorities (prehospital and initial hospital) for combined injuries, including blast lung injury and burn injury; blast lung injury and crush injury.*

Combined Injuries

Combined injuries, especially blast and burn injury or blast and crush injury, may be somewhat common during an explosive event. It is important to avoid tunnel vision that would address one injury but not another and thus cause harm. Remember, for example, fluid replacement issues when treating blast lung with another injury.

In all cases of combined injury, airway management and oxygenation/ ventilation are critical to survival, and should be achieved with standard techniques.

In combined burn/blast injury, while the burn injury will require significant

amounts of fluid resuscitation, care must be taken to avoid fluid overload, thereby increasing the risk of blast lung injury adult respiratory distress syndrome (ARDS). In the field, fluid resuscitation should be targeted to vital signs, to avoid hypotension; boluses should only be given as needed for this goal. The patient should ideally be brought to a facility with specific expertise in both trauma and burn management, or at the least trauma management. Fluid resuscitation can then be guided by urine output, central venous pressure, and systemic vascular resistance.

In combined crush/blast injury, the patient will need IV fluid boluses to reduce the danger of hyperkalemic cardiac arrest on release of the entrapped tissue. A standard 20 cc/kg. bolus (about 2 L in the adult) will likely offer some protection, but continuous cardiac monitoring should be established as soon as possible in the field, and responders should be prepared to treat hyperkalemia pharmacologically (calcium, insulin). In the hospital, the same principles as above apply to fluid resuscitation. Dialysis may be needed to treat electrolyte abnormalities or renal failure due to tissue destruction leading to myoglobinuria.

Objective

18. Describe the military experience in blast injury care, such as hemorrhage control issues and issues related to the use of tourniquets.

MILITARY EXPERIENCE IN BLAST INJURY CARE

The U.S. Military has gained extensive experience in dealing with blast injuries in Iraq and Afghanistan. They have actively sought and quickly adapted different strategies for treatment, particularly in the area of hemorrhage, which is the leading cause of preventable death. As a result, there has been a tremendous drop in mortality from previous wars.

Damage Control Surgery (DCS) is routinely applied for victims with significant hemorrhage to avoid the "Deadly Triad" of hypothermia, coagulopathy, and metabolic acidosis. The patient is transported directly to the operating room upon arrival, and resuscitation ensues concurrently with surgery. The goals of DCS are to quickly stop the bleeding, remove major contaminants, and leave the wound open (to avoid abdominal compartment syndrome). The patient is transferred to the ICU for continued resuscitation and normalization of blood pressure, body temperature, and coagulation factors. The patient returns for more definitive surgery 12-18 hours later.

Resuscitative techniques for major hemorrhage differ from current civilian medical practice. The initial resuscitation fluid of choice in massive transfusion (MT) is fresh thawed plasma (thawed fresh frozen plasma lasts 5 days at 4 deg C.); optimum ratio of plasma to crystalloid is 1:1 to avoid clotting factor dilution >50%. Crystalloid (which is acidotic, inflammatory, and has adverse effects on coagulation) is minimized, and colloid (Hextend) is preferred. Fresh whole blood is used routinely for MT. Cryoprecipitate and recombinant Factor VIIa is often used, early in the transfusion.

Tourniquets are carried by every soldier, each of whom has received instruction in its proper application. Liberal use is encouraged for any significant extremity hemorrhage. Early application of the tourniquet is

advocated for the avoidance of blood loss ("first resort not last resort"). Adverse effects in cases when tourniquets were applied inappropriately have not been seen.

New hemostatic dressings are used for non-extremity hemorrhage. The dressings are applied with pressure x 5 minutes, and then the patient is wrapped and transported. Personnel using these agents have been extremely impressed. HemCon bandage has been the predominant dressing used; a new formulation in the form of a roll that can be stuffed in wounds is now available. QuikClot has not been used as much due to its exothermic nature and the difficulty of debriding the powder from a wound; a new Advanced Clotting Sponge (ACS) form is now available, which can easily be removed from the wound. Another hemorrhage control agent, Celox, is currently undergoing testing but is not currently being used by the military.

SPECIAL CONSIDERATIONS

Objective

19. Describe the considerations that should be addressed for special needs patients such as children, women who are pregnant, the elderly, the disabled, and those with language barriers.

(The content related to this objective could be integrated into the appropriate sections, but general content related to these special needs populations could be taught in a separate section.)

Consideration should be given to the following groups:

- pregnant women
- children
- elderly people
- disabled people
- people with language barriers

Pregnancy

Blast injuries involving pregnant patients will warrant special consideration. Direct injury to the fetus is uncommon but injuries to the placenta are possible and must be detected. Patients in the second or third trimester of pregnancy should be admitted to the labor and delivery area for continuous fetal monitoring and further testing and evaluation. The placental attachment is at risk for primary blast injury because of the effect of spalling. In addition, tissues of different densities are accelerated by the blast wave at different rates, causing shearing injuries and placental abruption.

	A screening test for fetal-maternal hemorrhage should be performed on all women in the second or third trimester of pregnancy. A positive test requires mandatory pelvic ultrasound, fetal non-stress test monitoring, and obstetrics/gynecology (OB/GYN) consultation.
Children	A history of the event or patient's complaints may be difficult to obtain. An event history from bystanders and other victims could be the only source of information. Pulmonary contusion is one of the most common injuries from blunt thoracic trauma in pediatric patients. The injury may not be clinically apparent initially and should be suspected when abrasions, contusions, or rib fractures are present. A chest x-ray is essential in diagnosis especially when blast lung is suspected. Consideration should be given to specialized equipment for the prehospital environment, or non-pediatric hospitals. Identification of regional pediatric trauma facilities and pre-notification may be beneficial when transfers are indicated.
Elderly	The elderly may be at a higher risk of mortality and the in-hospital stay may be longer and more complicated. As with most traumatic injuries in this category of patient, underlying medical conditions may be exacerbated by the effects of a blast injury, or some injuries may be masked by pre-existing conditions. Orthopedic injuries may be more prevalent as a result of tertiary blast injuries due to a decrease in bone density and reduced body mass. Blunt chest trauma should be of special consideration due to the risk for pulmonary deterioration in the several days post-injury, and patients should be monitored carefully regardless of their initial presentation. Decontamination methods may need modification to accommodate patients with limited mobility. Technical decontamination of medical equipment such as wheelchairs, walkers and other walking aides may be needed.
Disabled	Extra consideration should be give to patients with underlying medical conditions. These conditions may not affect the acute treatment process, but should be considered for long term affects. In addition, untreated or inadequately treated fractures and infected wounds may lead to severe and long lasting disabilities in this group of patients.
Language Barriers	Since most bombing events occur in public places or large venues, a diverse population speaking multiple languages may be an unforeseen obstacle. Other communication barriers to consider would be interaction with the deaf, hard of hearing, late-deafened and the deaf-blind. A history of the event maybe difficult to obtain as well as the individual history for the patient.

Reliance on friends, family members of the patient, or bystanders, for translation may be necessary in the prehospital environment. These individuals, if not injured, should accompany the patient to the hospital to ensure communication can continue. Maintaining a pool of certified medical interpreters to include sign language, or access to telephone translation services should be considered for large metropolitan hospitals.

PSYCHOLOGICAL ISSUES

Objective

20. Describe the factors that affect mental health during an explosive event.

Factors That Affect Mental Health

This section is designed to provide a brief background on the recognition, evaluation, and treatment of both victims and responders with psychological concerns from terrorist events involving explosions and bombs.

Acts of terrorism tend to erode the sense of security and safety that we normally enjoy. Terrorism challenges the stability we enjoy in a predictable, orderly, and controlled world. Feelings of anger, frustration, helplessness, fear, guilt, distress, and a desire to seek revenge are all common responses.

In a terrorist event, there is:

- Little or no warning—Most events occur without warning, which makes it difficult for individuals to prepare psychologically. This lack of warning causes a perceived loss of control, a sense of helplessness, and a feeling of vulnerability.
- Unknown duration of the event—Depending on the terrorist act, there may be an uncertain end point that could intensify the psychological effects.
- Potential threat to personal safety—Due to the nature of terrorist events, people may feel personally targeted or threatened. In addition, the fear of further attacks may make them question the safety of other buildings and locations. They may feel no place is safe to seek shelter. Responders may also have to deal with the threat of secondary devices placed just to kill or injure those who respond to the scene.
- Unknown health risks—Health risks from unknown agents also contribute to the psychological effects of terrorism. Long term health risks would be a major fear.

Humans have a strong natural ability to recover from traumatic events. For most, the feelings of fear and anxiety will gradually decrease over time, but some will need professional help to totally recover.

Tips for both responders and planners include:

- Promotion of safety: help people meet the basic needs for shelter and food, provide a ‘recovery environment’ to include limited exposure to news and other media related to the event, encourage those who are relocated to return only when their areas are deemed safe.
- Promote calm: offer accurate information about the event and the efforts underway to help the situation.

	▪ Promote connectedness: help to reunite families and friends, establish a sense of normalcy for children by reinforcing parent-child bond, reuniting children with playmates, and reestablishing if possible, school and other safe environments. ▪ Promote self-efficacy: give practical suggestions and referrals that move people to help themselves. ▪ Promote hope: direct people to services that are available, remind people (if you know) that more assistance will be arriving.
Resources	http://www.bt.cdc.gov/masscasualties

PATIENT CASES

These patient cases are provided to assist in facilitating discussion for the individual objectives previously identified. The following patient cases are based on an explosion at a subway station and follow the assessment and treatment of four patients in the prehospital and hospital settings. The four patient cases include blast lung, combined injuries, blast brain and crush injuries.

Background

Two IEDs hidden in backpacks have exploded in separate cars of a southbound subway train that was stopped at the station. A few minutes later, a car bomb exploded in front of the main entrance of the station.

The two IEDs in the subway cars were contained in small backpacks or briefcases. Both contained shrapnel, which increased the injuries. Those immediately surrounding the blast were killed instantly. The glass windows were blown out but there was little structural damage to the cars except in the immediate area of the bombs. The severity of injuries decreased with further distance from the blast. The car bomb at the front of the station was a much larger explosion and caused major structural damage to the building. Walls collapsed and many people were trapped. The structural damage, debris and the number of injured has caused a major delay in the rescue effort.

The subway blast site is a scene of devastation and confusion. The area has been declared clear of further explosive hazards, but the scene is littered with glass and metal debris that pose an injury risk to patients and rescuers. The site has been secured and is now considered safe. Teams have completed initial triage.

The two subway cars had about 100 people riding in each when the IEDs detonated. 200 more people were in the lobby and nearby outside areas when the car bomb exploded. Approximately 400 total injured at the scene, located throughout the entire blast area. The initial triage numbers are: 68 Immediate, 117 Delayed, 97 Minor and 35 Deceased. A large number of Minor injured and untriaged people have left the scene and are presumed to be going directly to a hospital.

Triage for an explosive event poses different challenges from triage for other emergencies. A blast wave can cause severe internal injuries that are not immediately apparent, which is a very dangerous situation for patients. Patients also may have combined blast, ballistic, and burn injuries, including soft tissue injuries that can be difficult to detect. Accurate and efficient triage is extremely important and overtriage can delay recognition and treatment for patients with hidden or delayed injuries.

As many as 75 % of the victims at a blast event will go to hospitals on their own or will be taken to hospitals by people at the scene. These patients may not be badly injured, or they might have hidden injuries they are not aware of. They may arrive at the hospital before the most severely injured people who arrive by ambulance. This causes problems associated with inadequate surge capacity. Self-referred patients create a difficult situation at the hospital, because these people have not been assessed, triaged, or decontaminated. Hospitals must be prepared to decontaminate and triage large numbers of patients who arrive on their own.

Patient #1:

Your patient is a young male who was seated in one of the subway cars where the first IED exploded. He was moved to the lobby and was sitting against the wall when the second bomb exploded. He is conscious but does not respond appropriately to your questions. He keeps shouting, "What? What are you saying?"

He has been initially triaged as Delayed. As you visually survey the patient, you note he is now experiencing some difficulty in breathing and cyanosis is present on his face and hands. He has obvious signs of trauma on his face, chest, and extremities, including lacerations and bruising.

Prehospital Treatment

What do you do first?

a. Do a rapid primary survey and perform any necessary interventions to ensure an adequate airway is maintained.
b. Identify hemorrhage and treat appropriately
c. Start high flow oxygen and two large bore IVs wide open to see if his condition improves before completing your assessment.
d. Immediately place him flat on backboard and place C-Collar and head immobilization devices

Correct answer is: a

In this situation, the first priority is to secure the airway prior to transport. Large bore IVs are indicated, but administering too much fluid could cause serious damage to this patient. The cervical spine should be immobilized prior to transport. Control of hemorrhage is important, but the airway takes precedence.

Patient Assessment

Heart:	Good heart sounds, regular rhythm, bradycardia. Heart rate 56.
Head:	Neuro exam shows patient is slightly confused but follows commands. Moves all extremities. GCS = 14.
Mouth:	The patient has hemoptysis
Lungs:	You note tachypnea, wheezing, and decreased breath sounds. Respiratory rate 32.
Ear:	His hearing is impaired.
BP:	Blood pressure is 80 systolic.
Abdomen:	Abdomen is not tender, soft and not distended.

The patient tells you he cannot hear anything. Why is hearing loss an important observation in victims of an explosion?

a. Ear injuries need to be identified and may need to be treated by a specialist when the patient is stable.
b. Hearing loss caused by tympanic membrane rupture may or may not indicate other primary blast injuries.
c. Other types of barotrauma cannot be present in the absence of ear barotraumas.
d. Tympanic membrane rupture is the most common type of barotrauma after an explosion occurs.

Correct answers are: a, b, d

Lack of hearing could suggest tympanic membrane rupture, which may or may not indicate other primary blast injuries caused by a blast pressure wave. Tympanic membrane rupture is the most common type of barotrauma after explosions due to the lower pressure needed to injure the TM versus the lung or intestines. In the absence of tympanic membrane rupture, other significant barotrauma is unlikely, but not impossible. Patients with TM rupture should be observed for shortness of breath or abdominal pain for 4 to 6 hours to ensure no delayed barotrauma has occurred. If no TM rupture is present and the patient has no complaints or evidence of injuries on exam, the patient can be discharged. Damage to the deeper structures of the ear such as the ossicles or round window can occur and would be managed by a specialist when more serious injuries have been stabilized.

Your assessment has led you to suspect that this patient may be suffering from blast lung. What will your initial treatment include?

a. High flow oxygen with judicious fluid administration
b. High flow oxygen and wide open IV lines
c. Minimal oxygen flow with restricted fluid administration
d. Minimal oxygen flow with wide open IV lines

Correct answer is: a

For blast lung injury, you need to use high flow oxygen with judicious fluid administration to ensure tissue perfusion without volume overload. All patients with suspected or confirmed blast lung should receive supplemental high flow oxygen sufficient to prevent hypoxemia. However, in blast lung, wide open IV lines can cause fluid to accumulate in the lungs secondary to structural damage resulting in worsening pulmonary function.

What's Next?

This patient is being transported to County Memorial Emergency Department.

Hospital Treatment

When the patient arrives in the ED, he is receiving high flow oxygen via a non-rebreather mask and IV fluid at a maintenance rate. He is in respiratory distress with hemoptysis with declining oxygen saturations.

What treatment do you initiate?

a. Non-invasive Continuous Positive Airway Pressure (CPAP) treatment
b. Immediate surgical cricothyrotomy
c. Endotracheal intubation
d. Immediate needle thoracostomy

Correct answer is: c

Early endotracheal intubation should be done to secure the airway. CPAP treatment will not prevent airway compromise. Surgical cricothyrotomy would only be done emergently if unable to intubate the patient in a patient with a severely compromised airway. A needle thoracostomy is not indicated unless tension pneumothorax is suspected.

If the patient is intubated and is placed on a ventilator. What type of settings would you select?

a. High frequency ventilation
b. High tidal volume, rapid respiratory rate
c. Tidal volumes resulting in low peak inspiratory pressures
d. Permissive hypercapnia
e. Achieving a normal CO2 even if it requires high tidal volumes

Correct answers are: a, c, d

Pulse oximetry indicating decreased oxygen saturation can signal early blast lung injury even before other symptoms are present. High inspiratory pressures and volumes increase the risk of air embolism and pneumothorax. Hypercapnea with respiratory acidosis may result from relatively low pressures and volumes, but is acceptable to minimize additional pulmonary trauma from the ventilator itself (so-called permissive hypercapnea).

Since you suspect blast lung, you order a chest X-ray. What could you expect to see?

a. Bihilar "butterfly" pattern
b. Pneumothorax or hemothorax
c. Widened mediastinium
d. Subcutaneous emphysema
e. Pneumomediastinum

Correct answers are: a, b, d, e

All of these can be caused by pressure effects on the lungs except widened mediastinium. Widened mediastinium can occur with blunt trauma to the chest but not with blast lung.

The patient has improved, but the Chest X-ray shows a bilateral butterfly pattern diffusely. What do you recommend as the next step?

a. Admission to the ICU
b. Transfer to a hyperbaric chamber
c. Observe for evidence of intestinal injury
d. Observe for evidence of air embolism

Correct answers are: a, c, d

Patients diagnosed with blast lung may require complex management and should be admitted to an intensive care unit. Those with findings suspicious for early blast lung should be observed in the hospital. Patients should be watched closely for evidence of intestinal barotraumas or air emboli (to the heart, brain, spinal cord, etc) Patients with air emboli should be transferred to a hyperbaric chamber.

What's Next?

This patient has improved.

Discuss further actions for this patient.

Case Summary

So what really happened to this patient in the blast?

He was a young male riding in one of the subway cars when an IED exploded. He had been moved to the lobby by rescue teams and was sitting against the wall when the car bomb exploded.

From his delayed-onset symptoms and the chest x-ray showing a bihiliar "butterfly" pattern, you determined that he received a blast lung injury from one of the explosions, probably the first one.

He is able to maintain 96-97% oxygen saturation levels with supplemental oxygen.

This patient recovered from his injuries and was discharged from the hospital after eight days. Subsequent chest X-rays show resolution of the blast lung and no pneumothorax, hemothorax or pneumomediastinum. At discharge he exhibited no shortness of breath and maintained 99-100% oxygen saturation on room air.

The most important things to learn from this case are that:

- Rapid recognition of respiratory compromise at triage is essential.
- Hearing loss could be an indicator of blast lung, although this is not always so.
- Oxygen therapy, airway management, judicious IV fluids, chest X-ray and close observation for progressing complications are key components of care for this type of injury.
- Bradycardia can be present.

Patient #2

This patient is a 40-year-old female who is five months pregnant with first degree and superficial partial thickness second-degree flash burns to her face, hands, and legs. BSA burn involvement is approximately 22 percent. She has soft tissue lacerations on her face and upper torso caused by glass and metal. She says she was blown down by the blast.

Prehospital Treatment

Which would be your initial priorities for treatment?

a. Place her on her left side and check for fetal heart tones.
b. Establish large-bore IV.
c. Immobilize for possible spinal injuries.
d. Stabilize the airway and start supplemental oxygen.

Correct Answers are: b, c, d

Management of the mother is of primary concern and is the best way to ensure fetal survival. Securing the airway, stabilizing the cervical spine and providing supplemental oxygen are all high priorities with this patient. Large bore IV's should be started in trauma patients in case serious underlying injuries with hemorrhage occur. For women in the second or third trimester, lying on their left side can increase circulation, but fetal heart tone assessment is not part of initial management.

Early on in the management of this patient, which of the following do you consider?

a. Providing immediate pain control and sedation
b. Maintaining perfusion of the tissue
c. Administering tetanus toxoid to prevent infection
d. Avoiding overhydration of the lungs

Correct Answers are: a, b, d

IV access and fluid administration will allow for adequate fluid resuscitation and tissue perfusion, access for administration of antibiotics and pain medications. The possibility of over hydration should always be considered and the patient closely monitored for this. Over hydration for cases of blast lung is contraindicated. Tetanus toxoid, while important, is not an initial assessment priority.

Based on the mechanism of injury for this patient, she should be observed for signs and symptoms of all of the following conditions, except:

a. Abruptio placenta
b. Placenta previa
c. Concussion
d. Blast lung

Correct answer is: b

Placenta previa is a condition in which the placenta is formed low in the uterus and close to or covering the cervical opening. This condition is physiological and cannot be created through a trauma event.

During transport this patient becomes unresponsive and hypotensive, but is breathing adequately. Interventions you might perform include all the following except:

a. Insertion of a nasopharyngeal airway and high flow oxygen by non-rebreather mask
b. Administration of narcotic analgesia to overcome the pain of the injuries and burns
c. While maintaining cervical immobilization, elevating the spineboard so the patient is tilted on her left side to help shift the uterus off the vena cava, thus improving blood flow
d. Insertion of a second large bore IV and immediate administration of normal saline 20 ml/kg bolus

Correct answer is: b

Trauma or burn patients who become unresponsive require the establishment and protection of the airway. A nasopharyngeal airway is a reasonable initial intervention for a patient with good respiratory effort; however endotracheal intubation may be necessary. Elevation of the pregnant patient's left side in the second or third trimester is important for maintaining cardiac output. An IV bolus of normal saline is indicated for trauma-induced hypotension. Narcotic analgesia is contraindicated in the hypotensive and unresponsive patient.

What's Next?

The patient's airway is being maintained with a nasopharyngeal airway and high flow oxygen. The patient has been tilted to her left side with C-spine precautions in place and a second IV has been established. The patient is now enroute to the Emergency Department.

Hospital Treatment

As this patient arrives in the emergency department, what initial actions do you take to identify potential life threatening injuries?

a. Checking the distal extremities for foreign bodies
b. Checking for equal lung sounds and ordering and reading a chest X-ray
c. Checking for intra-abdominal injury
d. Checking for airway patency

Correct answers are: b, c, d

The primary assessment and initial management of this patient should include securing a patent airway, assessing breathing and lung sounds, and assessing for bleeding sources. Checking extremities for foreign bodies would occur during the secondary survey.

Which of the following *secondary* treatment priorities would you select for this patient?

a. Checking for tympanic membrane injury
b. Treating burns and wounds
c. Evaluating for corneal abrasions
d. Placing a chest tube or performing a needle thoracostomy for simple pneumothorax

Correct answers are: a, b, c

Treatment for plethora is a primary treatment priority, not secondary. All other interventions are appropriate as secondary treatment priorities. Although this patient meets criteria for transfer to a burn unit, only critical burn patients are being transferred during this event.

What other consultations would be useful in the emergency department for this patient?

a. Plastic surgery consult for possible scarring of the face
b. OB and/or L&D consultation for fetal monitoring
c. Call regional burn center for guidance on management for potential complications
d. Critical care consultation for blast lung injury

Correct answers are: b, c, d

An OB or L&D consultation for fetal assessment and monitoring would be appropriate for this patient with a 22-week gestational age. A critical care consultation is indicated if you suspect blast lung injury. A plastic surgeon consultation would not be initiated in the emergency department in the initial phase of care during a mass casualty incident (MCI).

What specific considerations do you have related to a pregnant patient presenting after a blast injury?

a. Primary injuries to the fetus are common.
b. Placental abruption can occur.
c. Fetal monitoring should be initiated.
d. Rhogam injection for Rh negative mother

Correct answers are: b, c, d

Because the fetus is surrounded by amniotic fluid, direct injury to the fetus is relatively uncommon. Injuries to the placenta are more common due to the effect of pressure waves on tissues of different densities (i.e. the placenta and uterus). Different tissue densities accelerate at different rates and this can lead to shearing forces and abruption. After life-threatening conditions have been stabilized, patients in the second or third trimester of pregnancy who have been exposed to blast injury should be admitted to the labor and delivery area for continuous fetal monitoring. There is a risk of mixing maternal and fetal

blood, which indicates the need for a pelvic ultrasound and helps to guide Rh immune globulin therapy in an Rh negative mother.

What's Next?

This patient has improved.

Discuss further actions for this patient.

Patient Summary

This 40-year-old female reported she was blown down by the bomb blast. She is five months pregnant and had first degree and superficial second-degree flash burns to her face, hands, and legs with BSA burn involvement approximately 22 percent. Flying glass and metal caused soft tissue lacerations on her face and upper torso.

Key points for pregnant patients injured in an explosive event are:

- Pregnant patients demonstrate anatomical and physiological differences when compared to non-pregnant trauma patients, which can modify assessment findings and subsequent interventions.
- The priorities of care in the pregnant patient are the same as those for the non-pregnant patient. Optimizing maternal airway, breathing and circulation will optimize the fetal outcome.
- Blast patients with multiple injuries present unique challenges for maintaining airway while addressing inadequate tissue perfusion.
- Hospitals should be prepared to treat and admit patient with degrees of injury or types of conditions they are not accustomed to, because the system may be overwhelmed.

After consultation with the burn unit, this patient was not transferred due to the large volume of critical burn patients. She was discharged four weeks later with instructions to follow up with her obstetrician.

Patient #3

This patient is a 50-year-old male who was seated in one of the subway cars when the blast occurred. He was thrown about 20 feet against the side of the car. He was initially triaged as Minor with only minor cuts on the head, face, and upper body from flying glass. It has now been more than an hour since the blast.

Extrication, the large number of critical patients, and a lack of personnel and transport vehicles have delayed this patient from receiving ALS care and transportation. Information on the triage tag states that the patient originally appeared as conscious and alert; oriented to person, place, time, and events; complained of a severe headache; with stable vitals.

Prehospital Treatment

Head: Initial assessment reveals he is no longer oriented to person, time, and place. He seems to be having difficulty processing your questions. His verbal responses are confused; he responds with some inappropriate words. GCS = 11
Eyes: There is some delay in pupillary response; his eyes open in response to your voice.
Lungs: Respiration is 24 per minute.
Arm: He has localized motor response to pain.

With this assessment information, what is the next step in treating this patient?

a. Administer bolus IV of saline over 5 minutes
b. Mark for transport as Immediate to nearest ED
c. Continue to monitor in casualty collection area
d. Sedate the patient with midazolam (1 to 2 mg IV push)

Correct answer is: b

As his level of orientation is changing, he needs evaluation in the hospital for a potential blast brain injury. Sedating him or providing a fluid bolus would not be appropriate treatments for a brain injury. Mark for transport as Immediate to the nearest ED.

Given the results of your assessment, what will your treatment include?

a. High-flow oxygen with a non-rebreather mask
b. Hyperventilate the patient with a BVM
c. Stabilize the patient's c-spine with a long backboard and collar
d. IV access with D5W at fluid maintenance rate
e. IV access with NaCl at fluid maintenance rate

Correct answers are: a, c, e

Supplemental high flow oxygen may decrease secondary brain injury and should be used whenever possible in this setting. Do not hyperventilate because it can cause cerebral ischemia and should be reserved for clinical circumstances where herniation is strongly suspected. Using D5W leads to more tissue swelling since it leaves the vascular space rapidly. An intravenous access site is preferred, but should only be accomplished after higher priorities are addressed at the mass casualty scene.

As the patient is going through a re-triage, you note that his pulse is about 130 beats per minute. This finding along with bleeding from multiple small wounds in the abdomen might indicate:

a. The patient has a ruptured abdominal aortic aneurism.
b. The patient has a potential for significant abdominal injuries due to shrapnel.
c. The increased pulse rate is an indicator of increased intracranial pressure.
d. The increased pulse rate is not a cause for concern.

Correct answer is: b

Even though you suspect the patient may have a significant head injury, any time there is a major change in the pulse rate, whether an increase or decrease, there is cause for concern. Increasing intracranial pressure would be suspected if there were a decrease of the patient's pulse, along with hypertension and either widening pulse pressures, or varying respirations (Cushing's Triad). However, the elevation in pulse rate in this scenario should be a clue that other significant injuries may be present that were not previously identified.

Hospital Treatment

When the patient arrives at the hospital, you learn there are currently no ED beds available and most exam rooms have two or three patients in each. The ED is overcrowded with a large number of walking wounded who arrived on their own. The staff has been trying to triage and decontaminate patients before they are allowed inside the ED. The EMS crew notifies you that there are three more Immediate patients who will arrive in the next 15 minutes.

What are the immediate priorities you must address to manage the current patient load in the ED?

a. Continue to triage and retriage all patients.
b. Keep walking wounded at casualty collection area outside ED.
c. Begin evaluation of this Immediate patient.
d. Move this patient to a holding area.

Correct answers are: a, b, c

Triage is a process, not a location. In an evolving mass casualty situation, patients' conditions and triage prioritization may change rapidly. Lower priority patients should not take up necessary emergency department resources, when higher priority patients need interventions. Patients triaged as Immediate take precedence for resources over lower priority patients.

Re-examination indicates the patient is now unconscious and hemodynamically stable. What are the immediate priorities you must address to manage this patient?

a. Intubation for airway protection
b. Mechanical ventilation to achieve normal CO_2
c. Suturing of small, dirty arm laceration
d. CT scan to evaluate for intracranial injury
e. Bilateral burr hole placement for cerebral decompression

Correct answers are: a, b, d

Endotracheal intubation is indicated for all treatable patients with suspected traumatic brain injury who are unresponsive or have a Glasgow Coma Score of less than or equal to 8. Airway protection, supplemental oxygenation, and evaluation of end-tidal or arterial CO_2 concentration should be achieved expeditiously, and prior to neuroimaging, initially with cranial CT scanning. Suturing of lacerations which are not actively bleeding, especially those that will require debridement and aggressive irrigation should be accomplished as a secondary or tertiary task. Burr holes may be performed for brain herniation when rapid decompressive craniotomy is unavailable.

Now that this patient is stabilized, you turn your attention to the small lacerations on the chest and extremities. You note that there are multiple lacerations from 1cm to 2.5 cm across the abdomen. Correct initial workup of these lacerations include:

a. Exploration and debridement of each wound
b. Immediate irrigation and suturing of each wound
c. CT scan of chest/abdomen to look for shrapnel
d. Probing of wounds with a cotton swab to determine depth

Correct answer is: c

Many IEDs are packed with nails, bolts and other objects designed to become projectiles when the bomb explodes. All patients with lacerations of indeterminate depth should be worked up as if each laceration was a penetrating injury. Irrigation, debridement and suturing may all be delayed.

What's Next?

This patient is improving and awaiting CT Scan results.

Discuss further actions for this patient.

Patient Summary

This 50-year-old male was in one of the subway cars when the blast occurred. He was thrown about 20 feet against the side of the car. He was initially triaged as Minor but an hour later had difficulty answering questions and was disoriented. At the ED, he was intubated and placed on mechanical ventilation. A CT scan was ordered to evaluate for intracranial injury. A CT scan of the abdomen revealed multiple small nail-like objects throughout the abdominal cavity. No significant loss of blood is noted.

Key points for patients who have brain and other injuries caused from an explosive event include:

- Triage is dynamic.
- Securing the airway is a priority.
- Do not aggressively hyperventilate.
- Do not be distracted by injuries that are not life-threatening
- Many innocuous seeming small lacerations may indicate shrapnel

This patient will have long-term brain injury and needs to be referred to a brain injury rehabilitation facility.

Patient #4

This patient is a 26-year-old female who was found in the far corner of the subway station four hours after the explosion with both legs trapped by part of a collapsed concrete wall. You note massive tissue damage and possible fractures to her legs.

Prehospital Treatment

Which of the following is true regarding compartment syndrome?

a. May occur in the absence of fracture.
b. Cannot occur in the presence of an open fracture.
c. Can lead to ischemia and limb loss if not treated promptly.
d. Loss of distal pulses is an early indicator.
e. Requires measurement of compartment measures to confirm the diagnosis.

Correct answers are: a, c, e

Though less common, compartment syndrome can occur in the absence of a fracture.
An open fracture does not guarantee decompression of the involved compartment.
Compartment syndrome must be treated aggressively; if left untreated, loss of life or limb can result.
While the 5 P's (pain, pallor, pulselessness, parasthesias, paralysis) are commonly cited as indicators of compartment syndrome, loss of pulses is generally a late sign. Compartment syndrome is suspected clinically, but can only be confirmed by measuring pressures in the affected compartments.

Due to the length of time the patient was trapped you suspect crush syndrome. Why should you begin aggressive treatment before extrication of the patient?

a. Dysrhythmias may occur immediately after freeing the limbs.
b. Toxins will be released into the bloodstream as soon as the extremities are freed.
c. Edema may prevent placement of IV lines after extrication.
d. Kidney function could be impaired after extrication.
e. With isolated crush syndrome, core temperature will drop significantly after extrication.

Correct answers are: a, b, c, and d

Muscle breakdown and cell lysis releases potassium and creatinine kinase/myoglobin into the bloodstream, which in high concentrations may produce toxic effects on heart rhythm and renal function. Significant soft tissue edema is likely with crushing injuries. Early placement or placement in a non-injured area of adequate vascular access will facilitate fluid resuscitation. Hypothermia may occur during or after resuscitation due to other associated trauma and the administration of IV fluids, but not with isolated crush syndrome.

What will your initial treatment priorities include?

a. High flow oxygen
b. Coordinate time of extrication
c. Apply ice directly to the injury sites
d. IV NaCl with 1 to 2 liter bolus just prior to release

e. Administer 2 mEq/kg of sodium bicarbonate just prior to extrication

Correct answers are: a, b, d, e

Supportive care with supplemental oxygen and fluid resuscitation are standard treatments for crush and compartment syndromes. Some experts recommend sodium bicarbonate prior to extrication, although data supporting this intervention is limited. Ice may worsen ischemia and damage to the injured areas and is therefore not routinely recommended.

What treatment would you consider providing during transport?
a. Splinting
b. Analgesia
c. Elevation of limb 6-12 inches above the heart
d. Cardiac monitoring
e. Snug elastic bandage

Correct answers are: a, b, c, d

Cardiac monitoring is critical because of the potential for life-threatening arrhythmias from hyperkalemia. Analgesia, splinting and gentle limb elevation are all indicated treatments, while a tight elastic bandage may restrict circulation and should not be applied.

What's Next?

This patient is being transported to County Memorial Emergency Department. In the field, she received high flow oxygen by non-rebreather mask, a 2 liter bolus of isotonic saline, and 2 milliequivalents per kilogram of sodium bicarbonate prior to extrication. She presents to the E.D. in moderate to severe pain.

Hospital Treatment

This patient arrives in the ED in moderate to severe pain.

Immediate interventions in the E.D. for this patient with a crushed extremity would include which of the following?

a. Verification of patent airway, and adequate breathing and circulation
b. EKG to assess for hyperkalemia
c. Drawing chemistries to check potassium levels and for other metabolic abnormalities
d. Sending a creatinine kinase or myoglobin level to assess for rhabdomyolysis
e. Debriding any dead tissue on the crushed limbs

Correct answers are: a, b, c, d

Supportive care and monitoring for expected effects of muscle and cellular injury and lysis are critical actions for initial hospital-based care. Monitoring for increased levels of creatinine kinase and myoglobin are appropriate laboratory assessments for these patients. Aggressive debridement may inadvertently remove tissue which may be ischemic, and should be left for subsequent surgical discretion. It is inappropriate on initial presentation to the E.D.

What fluid management strategies would you choose for this patient?

a. Fluids to ensure a minimum urine output of 1 to 2 ml/kg per hour
b. D5W as the resuscitation fluid to prevent hypoglycemia
c. Avoidance of initial fluids containing potassium because of the risk of hyperkalemia
d. Alkalinization of the urine as needed with fluids containing sodium bicarbonate
e. Fluid restriction to avoid exacerbation of edema in the crushed extremities

Correct answers are: a, c, d

Aggressive isotonic fluid resuscitation is indicated in patients with crush injury and compartment syndrome to maintain perfusion to tissues and prevent development of shock and acidemia. Muscle breakdown will release intracellular potassium risking complications from hyperkalemia. Alkalinization may be effective in enhancing urinary capture and excretion of myoglobin.

What next steps will you consider for this patient?

a. Fasciotomy of the lower extremity compartments may be indicated to treat the progression of compartment syndrome
b. Amputation of both lower extremities should be performed immediately to prevent sepsis
c. Systolic blood pressure should be kept at approximately 80 mm Hg (no higher) to prevent exacerbation of lower extremity hemorrhage
d. Hypothermia should be initiated to help prevent lower extremity ischemia
e. The patient should be completely undressed and undergo a full evaluation for other signs of trauma

Correct answers are: a, e

It is important to completely undress and assess trauma patients from head to toe without being distracted by a single area of obvious injury. Fasciotomy can sometimes prevent compartment syndrome, but amputation may be necessary after further assessment and monitoring. There is no role for controlled hypotension in the absence of uncontrolled internal hemorrhage. Hypothermia would not mitigate lower extremity ischemia.

What's Next?

This patient has improved.

Discuss further actions for this patient.

Patient Summary

This 26-year-old female was found in the far corner of the subway station. She was trapped by a collapsed concrete wall for more than four hours with both legs were pinned under debris. She received basic resuscitative measures in the field along with aggressive fluid resuscitation prior to extrication. She was treated for pain and monitored for hyperkalemia and acidosis.

This patient eventually underwent bilateral amputations and is currently in rehabilitation.

Key points when caring for a patient with crush injury and compartment syndrome include:

- Suspect crush injury and compartment syndrome in an entrapped patient who must be extricated.
- Know the early signs for complications of crush injury and compartment syndrome (such as hyperkalemia, rhabdomyolysis, hypotension, acidosis, sepsis)
- IV fluid resuscitation and possibly sodium bicarbonate should be administered prior to extrication of an entrapped patient to prevent shock.
- Patients with crush injury should be monitored for the development of hyperkalemia and rhabdomyolysis.
- Monitoring of fluid status through urinary output or other reliable means is important.

TEST

Question #1

Which of the following are *common* hazards that could be encountered in an explosive event? Select all that apply.

a. Building collapse
b. Electrical hazards
c. Secondary devices
d. Noise
e. Civil unrest

Correct answers are: A, C, D

Even though noise and electrical hazards may be encountered, they are not common hazards in an explosive event. Civil unrest most likely will be uncommon. However, fear and frustration can be expected among victims.

Question #2

Which of these factors may complicate effective triage during an explosive event? Select all that apply.

a. Explosive devices packed with sharp devices such as nails.
b. Victims must be transported from the scene immediately.
c. Most casualties will suffer temporary blindness.
d. Some severe injuries may not be detectable right away.
e. Most patients will be able to walk but not able to talk.

Correct answers are: A, D

The factors that complicate triage include terrorists' use of explosive devices that contain of shrapnel and sharp objects, severe internal injuries that are not immediately detectable. Also, severe soft tissue injuries may not be initially apparent. Another complicating factor may be overtriage that reduces care for hidden or delayed injuries.

Question #3

The majority of patients at the scene of an open-space explosion

a. Are dead
b. Have sustained life-threatening critical injuries requiring immediate intervention
c. Have minor injuries, including lacerations, fractures, and abrasions
d. Will wait for EMS to process them through a field triage protocol

Correct answer is: C

Most patients at the scene of a bombing have relatively minor injuries, and will self-triage and refer to the closest facility.

Question #4

The damage and injuries that result from a high explosive detonation depend on which of the following? Select all that apply.

a. Type of explosive used
b. Amount of explosive used
c. Location of the explosion
d. Victim's proximity to the blast

Correct answers are: A,B,C,D

Several factors affect the level and types of injuries that patient suffer. The amount and composition of the materials as well as the type of device used to make the bomb affect the size and destructiveness of the blast. The environment of the blast, whether the bomb is detonated in a closed or open area, and any intervening protective barrier also have effects on the resulting injuries. The location of the victim when the blast occurred is also a factor in the severity of injuries.

Question #5

Which basic blast mechanism is most likely to affect a patient's gas filled organs and structures?

a. Primary blast mechanism
b. Secondary blast mechanism
c. Tertiary blast mechanism
d. Quaternary blast mechanism

Correct answer is: A

Primary blast mechanism refers to the intense over-pressurization impulse created by a high-order detonation. The blast wave (which can affect gas filled organs and structures) causes damage at the tissue-fluid/gas interface. Damage is characterized by anatomical and physiological changes from the direct or reflective over-pressurization force impacting the body's surface.

Question #6

The shock wave from a blast causes injuries through a combination of different mechanisms including:

a. Compression, scalding and claudication
b. Spalling, shearing, implosion and irreversible work
c. Implosion, compression, scalding and claudication
d. Shearing, implosion and claudication

Correct answer is: B

Spalling, implosion and shearing are thought to be three mechanisms that cause blast injuries. Irreversible work is currently being researched as a more likely mechanism of injury. An explosive detonated within an enclosed space places patients inside at greater risk of injury than who are outside. Head injuries account for approximately 50-70 % of all deaths but most head injuries are non-lethal. Blast lung (pulmonary barotrauma) is a major cause of morbidity and mortality that often causes immediate death, but may present as late as 48 hours after explosion.

Question #7

Which of the following defines primary blast injury?

a. Unique to high explosive detonations
b. Results from penetrating or blunt trauma
c. Typically involves the ear, lungs, and abdomen
d. Often occurs in isolation without evidence of additional injury

Correct answers are: A, C

By definition, primary blast injury is not the result of penetrating or blunt trauma and it rarely occurs without evidence of secondary, tertiary, or quaternary injury.

Question #8

Secondary blast injuries include:

a. Toxic exposure
b. Burns
c. Fractures
d. Penetrating trauma
e. Blunt trauma

Correct answers are: D, E

Secondary blast injuries result from flying debris and bomb fragments. The most common types of injuries are penetrating and blunt trauma.

Question #9

Quaternary blast injuries include which of the following? Select all that apply.

a. Burns
b. Complications of chronic disease as a result of the event
c. Chemical exposures as a result of the explosion
d. Blunt trauma
e. Traumatic amputation

Correct answers are: A, B, C

Quaternary blast injury includes all explosion-related injuries, illnesses, or diseases not due to primary, secondary, or tertiary mechanisms and exacerbation or complications of existing conditions. Blunt trauma is a secondary injury and traumatic amputation is caused by tertiary mechanisms.

Question #10

Which category of blast or explosive injury is a result of trauma caused by being thrown against a fixed object?

a. Primary
b. Secondary
c. Tertiary
d. Quaternary

Correct answer is: C

Primary blast injury (PBI) occurs as a direct effect of changes in atmospheric pressure caused by a blast wave. Secondary blast injuries occur when objects accelerated by the energy of the explosion strike a victim, causing either blunt or penetrating ballistic trauma. Tertiary blast injuries result from a victim's body being displaced by expanding gasses and high winds; trauma then occurs from tumbling and impacting objects. Quaternary injuries include everything else: inhalations of dust, smoke, carbon monoxide, and other chemicals; burns from hot gasses or secondary fires; and crushing injuries from structural collapses.

Question #11

Common primary blast injuries include:

a. Blast lung, concussion and tympanic membrane rupture
b. Penetrating chest trauma, fractures and traumatic amputations
c. Hyperglycemia, crush syndrome and COPD
d. Blast lung, penetrating abdominal injury and crush syndrome

Correct answer is: A

Primary blast injury is caused by the direct effect of blast overpressure on tissue. Since air is easily compressed, primary blast injury almost always affects air-filled structures such as the lung, ear, and gastrointestinal (GI) tract

Question #12

Which of the following are *true* about blast lung injury (BLI)? Select all that apply.

a. Bradycardia may be present.
b. Oxygen therapy, airway management, and judicious use of IV fluids are important.
c. Immediate needle thoracostomy should be performed.
d. Tetanus should be administered as a priority.

Correct answers are: A, B

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, or endotracheal intubation). Bradycardia can be present in a patient with blast lung injury.

Question #13

When treating patients with combined injuries, such as burns and blast lung or crush and blast lung, which of the following are true? Select all that apply.

a. Airway management and oxygenation are critical.
b. Avoid tunnel vision that results in focusing on one injury and not others.
c. Remember fluid replacement issues when treating blast lung combined with other injuries.
d. Blast lung should be treated as the priority.

Correct answers are: A, B, C

When treating patients with combined injuries, it is important to consider all of the injuries and not focus on one particular injury.

Question #14

Which of the following are NOT TRUE regarding blast injuries?

a. Tympanic membrane rupture can be used as a screening triage tool to indicate the presence of severe underlying injury and need for a minimum of 24-hours of observation.
b. Patients may present with combined injuries, especially blast and burn or blast and crush.
c. Treatment of blast lung is similar to treatment for pulmonary contusion.
d. Blast lung, globe rupture, abdominal organ perforation, and traumatic brain injury are all examples of primary blast injuries.
e. Secondary blast injuries caused by flying debris generated by the explosion are the most common cause of death in a blast event.

Correct answer is: A

Tympanic membrane rupture in and of itself does not indicate the need for prolonged observation. Stable patients without hemoptysis or tachypnea and in whom the primary evaluation reveals no evidence of other clinically significant injuries may be discharged if vital signs are stable after four to six hours of observation despite the presence of tympanic membrane rupture.

Question #15

What is the appropriate intervention for a patient who presents with tachypnea, wheezing, hemoptysis, cough, and chest pain following a blast event?

a. High flow oxygen and judicious intravenous fluid replacement
b. Low flow oxygen by nasal cannula to prevent barotraumas
c. Arterial blood gases and blood chemistry laboratory tests
d. Fluid boluses to increase urinary output for excretion of myoglobin

Correct answer is: A

Use high flow oxygen with judicious fluid administration to ensure tissue perfusion without volume overload. Patients with suspected or confirmed blast lung should receive supplemental high flow oxygen sufficient to prevent hypoxemia. In blast lung, wide open IV lines can cause fluid to accumulate in the lungs secondary to structural damage resulting in worsening pulmonary function.

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