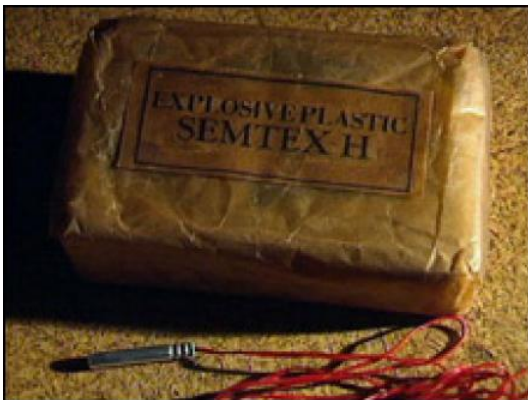


BLAST INJURIES

Blast injuries result in mortality rates ranging between about 8 percent in open-air blasts and 49 percent when the explosion occurs in a confined space. A majority of victims (approximately 70 percent) will sustain soft tissue injury and traumatic amputations will occur in approximately 11 percent of the cases. The principle mechanism behind the injuries is the creation of tremendous kinetic energy over a short period of time. We will discuss the injuries associated with explosions, along with their triage and treatment in this condensed module.

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

HE produce a defining supersonic over-pressurization shock wave. Examples of HE include TNT, C-4, Semtex, Nitroglycerin, Dynamite, and Ammonium Nitrate Fuel Oil (ANFO). Some sample illustrations of HE appear below.



Above: HE - Semtex with detonator



Right: HE - Nitroglycerin - liquid explosive

LE create 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. Images of LE are shown below:



Above: LE - Molotov Cocktail. (Photo courtesy of militaryimages.net)



Above: LE - Pipe Bomb



Left: LE - Aircraft used as a guided missile.

Explosive and incendiary bombs are further characterized based on their source, specifically, "manufactured" and "improvised".

"Manufactured" implies standard military-issued, mass produced, and quality-tested weapons. Manufactured (military) explosive weapons are exclusively HE based. "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. Terrorists will use whatever is available-illegally obtained manufactured weapons or improvised explosive devices (also known as IED'S) that may be composed of HE, LE or both.

There are four general types of injuries caused by explosion:

1. **Primary**, or "blast wave" injury, refers to injury caused by the intense over-pressurization impulse created by a detonated HE. Blast wave injuries are characterized by anatomical and physiological changes from the direct or indirect over-pressurization force impacting the bodies' surface. The HE "Blast wave" (over-pressure component) should be distinguished from "Blast wind" (forced superheated air flow). "Blast wind" may be encountered with both HE and LE, however "blast wave" is specific to HE only.
2. **Secondary** injuries are those injuries sustained by flying shrapnel and other objects.
3. **Tertiary** injuries are those injuries sustained by the body being physically thrown from the blast wind.
4. **Quaternary** are related injuries indirectly caused by the explosion.

These will be explored further below.

Table 1: Mechanisms of Blast injury

CATEGORY	CHARACTERISTICS	BODY PART AFFECTED	TYPES OF INJURIES
PRIMARY	Unique to HE, results from the impact of the over-pressurization wave with body surfaces	Gas filled structures are most susceptible: lungs, GI tract, and middle ear	-Blast lung(pulmonary barotrauma) - TM rupture and middle ear damage -Abdominal hemorrhage and perforation -Globe (eye) rupture -Concussion (TBI without physical signs of head injury)
SECONDARY	Results from flying debris and bomb fragments	Any body part may be affected	-Penetrating ballistic (fragmentation) or blunt injuries -Eye penetration (can be occult)
TERTIARY	Results from individuals being thrown by the blast wind	Any body part can be affected	-Fracture and traumatic amputation -Closed and open brain injury
QUATERNARY	-All explosion-related injuries, illnesses, or diseases not due to primary, secondary, or tertiary mechanism. -Includes exacerbation or complications of existing conditions.	Any body part can be affected	-Burns (flash, partial, and full thickness) -Crush injuries -Closed and open brain injury -Asthma, COPD, or other breathing problems from dust, smoke, or toxic fumes -Angina -Hyperglycemia, hypertension

LE are classified differently because they lack the self-defining HE over-pressurization wave. LE's mechanisms of injuries are characterized as due from (secondary) ballistics (fragmentation), blast wind (tertiary), and thermal. There is overlap between LE descriptive mechanisms and HE's secondary tertiary, and quaternary mechanisms.

Types of injuries:

Immediate death. Death from an explosion can be instantaneous and result from massive pulmonary hemorrhage accompanied by rapid suffocation. Other causes of immediate death from an explosion include pulmonary air embolism, significant head injury, bleeding out from a traumatic injury, crush injury, and impalement. Because of the blast wave and its damage, the patient dies in spite of immediate and high quality care. EMT-B and paramedics should consider death in any victim of an explosion under the following conditions:

- 1 Traumatic amputation along with absent vital signs.
- 2 Absence of effective ventilation or pulse.
- 3 Severe respiratory insufficiency caused by a blast effect.

Primary blast injuries: Primary blast injuries result from the blast wave created by HE. About 20% of the explosion victims will present with primary (blast wave) injuries. The extent of those injuries will depend on several factors, including:

- 1 Peak pressure of the initial blast wave
- 2 Duration of over-pressurization
- 3 Medium in which the explosion occurs (confined space or open area)
- 4 Distance from the source of the explosion

Primary blast injuries commonly affect the ear, respiratory system, and gastrointestinal system. The brain and cardiovascular system may also be affected (See Table 2).



Explosion

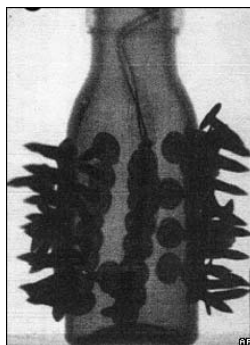
In the ear, the eardrum typically ruptures, especially when the over-pressure exceeds 5 psi. With extremely high over-pressures, the eardrum may be destroyed and the ossicles (bony structures) can be dislocated or fractured. At lower pressures, the eardrum may bleed without rupture. Signs and symptoms of eardrum rupture include pain, loss of hearing, and tinnitus. Blood may be present in the ear canal.

The respiratory system can sustain significant injury typically as a result of supersonic pressure caused by the blast wave. Over-pressurization at 40 psi will cause pulmonary injury such as pneumothorax, air embolism, interstitial emphysema, and subcutaneous emphysema. Pulmonary contusion is most common and generally found on the side of the body that was closest to the explosion. Signs and symptoms can be delayed up to 48 hours after the event.

Blast injury to the gastrointestinal tract should be suspected in anyone exposed to an explosion with signs and symptoms that include abdominal pain, nausea, vomiting, vomiting blood, rectal pain, testicular pain, unexplained Hypovolemia, and any finding suggesting an acute abdominal complaint. The colon is the most common site of hemorrhage and perforation. The perforated bowel may be immediately evident or may perforate after a delay of up to 48 hours. Solid organ laceration and testicular rupture are also seen with primary blast injury, but are less frequent and often associated with large blast loads.

Primary blast injury can cause concussion or traumatic brain injury, although this finding is difficult to differentiate from a concussion because of impact with another object. Myocardial contusion accompanied by signs of dysrhythmia or hypotension may develop.

Secondary blast injuries: Are caused by debris propelled by the blast wind of the explosion, resulting in both penetrating and blunt trauma. Individuals far from the scene of an explosion can be struck and injured by this debris. For example, after the 1998 terrorist bombing of the U.S. Embassy in Nairobi, Kenya, flying glass wounded victims up to 2 kilometers away. Terrorist devices often have additional objects such as nails, nuts and bolts, etc added to the explosive mixture to increase the effects of secondary blast injury. Military devices such as shells and grenades may be designed in such a way as to increase the number of fragments (shrapnel) flung by the explosion.



An unexploded device found in London, England.

Secondary blast injuries are much more common than primary blast injuries and are the most common causes of death in blast victims. The penetrating injuries occur most often in the exposed areas of the body such as the head, neck, and extremities. Secondary blast injuries may not be initially obvious. A seemingly small wound may mask the entrance wound for a large fragment. The EMS provider should also remember that blast fragments may be traveling up to five times faster than a military bullet.

Tertiary blast injuries: Are caused when the victim's body is propelled into another object by the blast winds. Tertiary effects result from the bulk flow of gas away from the explosion and often occur when the victim is in close proximity to the explosion. However, these injuries can take place relatively far from the point of detonation if the victim is located in the path of gases venting from a structure, such as a doorway, window, or hatch. Likewise, if the patient is in the alley, magnification of the blast wind may occur because of the configuration of the buildings.

Injuries from this mechanism depend on what the victim strikes and can range from simple contusions to impalement. Victims may tumble along the ground sustaining abrasions, contusions, and "Road rash".

Quaternary injuries: Include burns from fire or radiation, crush injury associated with structural collapse, poisoning from carbon monoxide or other toxic products of the explosion, and inhalation of dust or chemicals from the explosion. The unprotected human body can survive a blast with a peak over-pressure of 30 psi, but buildings and other structures collapse with stress of only a few pounds psi. This means that persons can survive the effects of the blast only to be killed or injured by collapsing buildings or other quaternary injuries.

Finally, the blast may be a vector for chemical and/or biological warfare agents.

Pre-hospital considerations: When faced with a major explosion, the EMT and Paramedic's job will be difficult. The predominant injuries found after an explosion will be penetrating and blunt trauma. Because the initial signs and symptoms of significant blast injury can be subtle, the early presentation of victims can be deceiving. Blast lung injury is the most common fatal injury among initial survivors of the blast. Pre-hospital medical care can follow some simple guidelines:

- 1 Initial care is similar to regular trauma care
- 2 Rapid evacuation increases the chance of survival
- 3 Follow the principles of disaster management-do not treat during triage
- 4 Resuscitation efforts in the field should be minimal due to the number of patients and their likelihood of survival.

An explosion that occurs in a confined space (vehicles, mines, buildings, and subways) is associated with greater morbidity. If the structure collapses, this markedly increases mortality.

The EMS provider should be alert for secondary devices and explosions. Foreign and domestic experience has shown that terrorists will often set a second device timed to explode 30 to 100 minutes after the first device has detonated. This second device is designed to kill and injure EMS, Fire, and Police personnel who will be at the scene. In some cases, the perpetrator of the explosion may be watching over the area of the explosion and either remotely detonate the second explosive or employ high-powered rifle fire to injure or kill responders. Coordinated, sophisticated, secondary attacks perpetrated by multiple persons have also been reported.

It is also important to suspect that one or some of the victims may have weapons, booby traps, and/or explosives. It is quite common for a bomber to become a victim of his own device.



Continued

Table 2: System-Injury/Condition

EARS/AUDITORY	<ul style="list-style-type: none">-BLOOD OOZING FROM THE MOUTH, NOSE, OR EARS-EARDRUM HYPEREMIA (CONGESTION OF BLOOD) HEMORRHAGE, OR RUPTURE-DEAFNESS-TINNITIS (RINGING OR BUZZING IN EAR)-EARACHE-TACHYCARDIA-DECREASED PULSE PRESSURE/FALL OF MEAN ARTERIAL BLOOD PRESSURE
CARDIOVASCULAR	<ul style="list-style-type: none">-MYOCARDIAL CONTUSION, MYOCARDIAL INFARCTION FROM AIR EMBOLISM, CARDIOGENIC SHOCK, PERIPHERAL VASCULAR INJURY, PERIPHERAL ISCHEMIA FROM AIR EMBOLISM, SHOCK-TACHYCARDIA-DECREASED PULSE PRESSURE/FALL OF MEAN ARTERIAL BLOOD PRESSURE
EXTREMITY	<ul style="list-style-type: none">-FRACTURES, AMPUTATIONS, CRUSH INJURY, BLOOD POOLING, BURNS, CUTS, LACERATIONS, ACUTE OCCLUSION OF AN ARTERY, AIR EMBOLISM INDUCED INJURY
GASTROINTESTINAL	<ul style="list-style-type: none">-ORGAN PERFORATION, HEMORRHAGE,-FRACTURE/ RUPTURE OF LIVER OR SPLEEN-MESENTERIC ISCHEMIA FROM AIR EMBOLISM-SEPSIS-NAUSEA-ABDOMINAL TENDERNESS-ABDOMINAL RIGIDITY
NEUROLOGIC	<ul style="list-style-type: none">-CONCUSSION, CLOSED BRAIN INJURY, OPEN CNS INJURY,-STROKE FROM AIR EMBOLISM-SPINAL CORD INJURY-PRIMARY BLAST INJURY CAN CAUSE CONCUSSION WITHOUT A DIRECT BLOW TO THE HEAD-VERTIGO-RETROGRADE AMNESIA
OCULAR	<ul style="list-style-type: none">-PERFORATED EYE, FOREIGN BODIES, AIR EMBOLISM, AND ORBITAL FRACTURES,-UP TO 10% OF SURVIVORS HAVE SIGNIFICANT EYE INJURY-EYE IRRITATION-BLINDNESS-RETINAL ARTERY AIR EMBOLISM
RENAL	<ul style="list-style-type: none">-RENAL CONTUSION, KIDNEY LACERATION, ACUTE RENAL FAILURE DUE TO SHOCK, TESTICULAR RUPTURE
RESPIRATORY	<ul style="list-style-type: none">-BLAST LUNG, HEMOTHORAX, PNEUMOTHORAX, PULMONARY CONTUSION, PULMONARY HEMORRHAGE, AIR EMBOLISM ASPIRATION,-CYANOSIS, ECCHYMOSIS, PETECHIA, TACHYPNEA, DYSPNEA, HEMOPTYSIS(COUGHING UP BLOOD), RALES, CHEST PAIN

General Post START Triage treatment strategies for care providers:

1. Listen for breathing; look for chest movement; feel for a pulse.
2. Establish an airway
 - Chin lift, jaw thrust, stabilize head, avoid neck movement
 - Intubation—avoid head tilt if neck injuries
3. Perform rescue breathing and chest compressions if indicated and adequate personnel on scene
4. Cover open chest wounds, treat tension pneumothorax
5. Manage bleeding
 - Control bleeding with pressure
 - Internal bleeding needs to be controlled surgically
 - Maintain the victim's mentation (mental status)
 - Monitor blood pressure (patient needs at least a systolic of 100 or seek ALS provider)
6. Burns
 - Cover large surfaces with cleanest covers available (preferably sterile multi-trauma dressing)
7. Impaled objects
 - Do not remove impaled objects unless the object is interfering with the airway
 - If object prevents transport it may need to be shortened
8. Long bone fractures
 - Splint to prevent instability
 - Splint to prevent bleeding
9. Eye injury
 - Up to 10% of all blast survivors have significant eye injuries.
 - These injuries involve perforations from high velocity projectiles and can present for care days, weeks, or months after the event
 - Symptoms include:
 - Eye pain or irritation
 - Foreign body sensation
 - Altered vision
 - Periorbital swelling or contusions
 - Findings can include:
 - Decreased visual acuity
 - Globe perforation
 - Sub conjunctival hemorrhage
10. Pulmonary
 - Blast lung
 - The most common fatal primary blast injury among initial survivors.
 - Signs of severe blast lung usually present at the time of the initial evaluation but can present up to 48 hours after the explosion

- The clinical triad of apnea, bradycardia, and hypotension characterize blast lung
- Pulmonary injuries vary from petechiae (small hemorrhage spot) to confluent hemorrhage
- Blast lung should be suspected for patients with:
 - Dyspnea
 - Cough
 - Hemoptysis (spitting or coughing up blood)
 - Chest pain
- This victim may need a chest tube and should be forwarded to an ALS provider as soon as available

11. Ear injury

- Primary blast injuries of the auditory system cause significant morbidity, but are easily overlooked. Injury is dependant on the orientation of the ear to the blast. TM perforation is the most common injury to the middle ear. Signs of ear injury are usually present at the time of the initial evaluation and should be suspected for anyone presenting with hearing loss, tinnitus, and vertigo, or bleeding from the external ear canal.
- If there is blood coming from the ears suspect the blast was powerful enough to cause pulmonary injury (blast lung) or hollow organ injury

12. Abdominal injuries: (gas-containing sections of the GI tract are most vulnerable to primary blast effect.)

- Immediate or delayed bowel perforation
- Internal hemorrhage
- Solid organ lacerations
- Testicular rupture

13. Blast abdominal injury should be suspected in anyone exposed to an explosion with:

- Abdominal pain
- Nausea
- Vomiting
- Vomiting blood
- Rectal pain
- Testicular pain
- Unexplained Hypovolemia
- Distention/rigidity

14. Brain injury

- Primary blast waves can cause concussions or mild traumatic brain injury without a direct blow to the head. Consider the proximity of the victim to the blast.
- Patient may present with
 - Headache
 - Fatigue
 - Poor concentration
 - Lethargy
 - Depression
 - Anxiety
 - Insomnia

