BLAST INJURIES

Fact Sheets for Professionals

National Center for Injury Prevention and Control
Division or Injury Response

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Blast Injuries

In an instant, an explosion or blast can wreck havoc; producing numerous casualties with complex, technically challenging injuries not commonly seen after natural disasters such as floods or hurricanes. To address this issue, Centers for Disease Control and Prevention (CDC), in collaboration with partners from the Terrorism Injuries Information, Dissemination and Exchange (TIIDE) Project, as well as other experts in the field, have developed fact sheets for health care providers that provide detailed information on the treatment of blast injuries.

These fact sheets address background, clinical presentation, diagnostic evaluation, management and disposition of blast injury topics and are available in many languages including Arabic, Bengali, Spanish, French, Chinese, Hindi, Marathi, Russian, and Urdu.

Additional terrorist bombing and mass casualty event preparedness and response information for professionals including fact sheets, multimedia tools, and communication messages are available for download and order from CDC's website at http://emergency.cdc.gov/BlastInjuries.

Post these fact sheets in emergency departments where visible and accessible to staff only and include the fact sheets in your hospital emergency plan binders.

Note: Please use caution with posting these fact sheets in public areas, such as hospital waiting rooms, as this information may cause alarm.

BLAST INJURIES

Essential Facts

Essential Facts

Key Concepts

- Bombs and explosions can cause unique patterns of injury seldom seen outside combat
- Expect half of all initial casualties to seek medical care over a one-hour period
- Most severely injured arrive after the less injured, who bypass EMS triage and go directly to the closest hospitals
- Predominant injuries involve multiple penetrating injuries and blunt trauma
- Explosions in confined spaces (buildings, large vehicles, mines) and/or structural collapse are associated with greater morbidity and mortality
- Primary blast injuries in survivors are predominantly seen in confined space explosions
- Repeatedly examine and assess patients exposed to a blast
- All bomb events have the potential for chemical and/or radiological contamination
- Triage and life saving procedures should never be delayed because of the possibility of radioactive contamination of the victim; the risk of exposure to caregivers is small
- Universal precautions effectively protect against radiological secondary contamination of first responders and first receivers
- For those with injuries resulting in nonintact skin or mucous membrane exposure, hepatitis B immunization (within 7 days) and age-appropriate tetanus toxoid vaccine (if not current)

Blast Injuries

- Primary: Injury from over-pressurization force (blast wave) impacting the body surface
  - TM rupture, pulmonary damage and air embolization, hollow viscus injury
- Secondary: Injury from projectiles (bomb fragments, flying debris)
  - Penetrating trauma, fragmentation injuries, blunt trauma
- Tertiary: Injuries from displacement of victim by the blast wind
  - Blunt/penetrating trauma, fractures, and traumatic amputations
- Quaternary: All other injuries from the blast
  - Crush injuries, burns, asphyxia, toxic exposures, exacerbations of chronic illness

Primary Blast Injury

Lung Injury

- Signs usually present at time of initial evaluation, but may be delayed up to 48 hours
- Reported to be more common in patients with skull fractures, >10% BSA burns, and penetrating injury to the head or torso
- Varies from scattered petechiae to confluent hemorrhages
- Suspect in anyone with dyspnea, cough, hemoptysis, or chest pain following blast
- CXR: “butterfly” pattern
- High flow O2 sufficient to prevent hypoxemia via NRB mask, CPAP, or ET tube

U.S. Department of Health and Human Services
Centers for Disease Control and Prevention

Essential Facts

Primary Blast Injury (continued)

- Fluid management similar to pulmonary contusion; ensure tissue perfusion but avoid volume overload
- Endotracheal intubation for massive hemoptysis, impending airway compromise or respiratory failure
  - Consider selective bronchial intubation for significant air leaks or massive hemoptysis
  - Positive pressure may risk alveolar rupture or air embolism
- Prompt decompression for clinical evidence of pneumothorax or hemothorax
- Consider prophylactic chest tube before general anesthesia or air transport
- Air embolism can present as stroke, MI, acute abdomen, blindness, deafness, spinal cord injury, claudication
  - High flow O_2; prone, semi-left lateral, or left lateral position
  - Consider transfer for hyperbaric O_2 therapy

Abdominal Injury

- Gas-filled structures most vulnerable (esp. colon)
- Bowel perforation, hemorrhage (small petechiae to large hematomas), mesenteric shear injuries, solid organ lacerations, and testicular rupture
- Suspect in anyone with abdominal pain, nausea, vomiting, hematemesis, rectal pain, tenesmus, testicular pain, unexplained hypovolemia
- Clinical signs can be initially subtle until acute abdomen or sepsis is advanced

Ear Injury

- Tympanic membrane most common primary blast injury
- Signs of ear injury usually evident on presentation (hearing loss, tinnitus, otalgia, vertigo, bleeding from external canal, otorrhea)

Other Injury

- Traumatic amputation of any limb is a marker for multi-system injuries
- Concussions are common and easily overlooked
- Consider delayed primary closure for grossly contaminated wounds, and assess tetanus immunization status
- Compartment syndrome, rhabdomyolysis, and acute renal failure are associated with structural collapse, prolonged extrication, severe burns, and some poisonings
- Consider possibility of exposure to inhaled toxins (CO, CN, MetHgb) in both industrial and terrorist explosions
- Significant percentage of survivors will have serious eye injuries

Disposition

- No definitive guidelines for observation, admission, or discharge
- Discharge decisions will also depend upon associated injuries
- Admit 2nd and 3rd trimester pregnancies for monitoring
- Close follow-up of wounds, head injury, eye, ear, and stress-related complaints
- Patients with ear injury may have tinnitus or deafness; communications and instructions may need to be written

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BLAST INJURIES

Abdominal Blast Injuries

Background

Abdominal blast injuries are a significant cause of injury and death. The actual incidence of abdominal blast injury is unknown. Incidence and clinical presentation of abdominal blast injury will vary significantly depending upon the patient and the nature of the blast. Underwater blasts carry a significantly greater risk of abdominal injury. Children are more prone to abdominal injuries in blast situations due to their unique anatomy. (For further information please refer to CDC's "Blast Injuries: Pediatrics" fact sheet.)

Clinical Presentation

Gas-containing sections of the GI tract are most vulnerable to primary blast effect. This can cause immediate bowel perforation, hemorrhage (ranging from small petechiae to large hematomas), mesenteric shear injuries, solid organ lacerations, and testicular rupture. Blast abdominal injury should be suspected in anyone exposed to an explosion with abdominal pain, nausea, vomiting, hematemesis, rectal pain, tenesmus, testicular pain, unexplained hypovolemia, or any findings suggestive of an acute abdomen. Clinical findings may be absent until the onset of complications:

- Clinical presentation of abdominal blast injury may be overt, or subtle and variable, and may include: abdominal pain, rebound tenderness, guarding, absent bowel sounds, nausea and vomiting, fever, and signs and symptoms of hypovolemia or hemorrhage. Victims of closed space bombings are at risk for more primary blast injuries, including abdominal injury.
- Predominant post-explosion abdominal injuries among survivors involve standard penetrating and blunt trauma (secondary and tertiary blast injury), but include primary blast injuries, including ischemia secondary to arterial gas embolism.
- Abdominal injuries are particularly severe in underwater blasts; the lethal radius of an underwater explosion is about three times that of a similar explosion in air because waves propagate faster and are slower to lose energy with distance due to the relative incompressibility of water.
- Children are more prone to abdominal blast injury
  - smaller and more pliable walls offer less protection
  - thin abdominal walls offer less protection
  - proportionately larger organs render children more vulnerable to injuries, especially to liver and spleen
- Most common abdominal blast injuries include:
  - Primary: abdominal hemorrhage and perforation (colon most vulnerable to perforation)
  - Secondary: penetrating and blunt abdominal trauma
  - Tertiary: blunt and penetrating abdominal trauma
  - Quaternary: crush injury to abdomen and abdominal wall

Diagnostic Evaluation

- Work-up similar to standard blunt and penetrating abdominal trauma
  - Serial abdominal examinations, as presentation may be delayed; serial exams may be difficult in young children
  - Laboratory studies
  - Radiological studies: free air, unexplained ileus, intra-abdominal hematoma/hemorrhage, solid organ contusion/laceration, intra-abdominal abscess

Initial Management

- ABCs (airway, breathing, circulation) as for all trauma patients
- Nothing by mouth
- Avoid removal of penetrating objects in emergency room (operative intervention due to risk of hemorrhage)
- Antibiotics and tetanus immunization
- Serial exams and laboratory monitoring
- Radiological studies: plain abdominal films, computed tomography [CT] scan, Focused Abdominal Sonography for Trauma (FAST)

Disposition

- High degree of suspicion for missed or delayed abdominal injuries, including serial exams, close follow-up, and strict return instructions should signs or symptoms of abdominal injury manifest after discharge
- Appropriate referral to trauma center as needed

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BLAST INJURIES

Crush Injury and Crush Syndrome

Background

In a terrorist attack, crush injury and crush syndrome may result from structural collapse after a bombing or explosion. Crush injury is defined as compression of extremities or other parts of the body that causes muscle swelling and/or neurological disturbances in the affected areas of the body. Typically affected areas of the body include lower extremities (74%), upper extremities (10%), and trunk (9%). Crush syndrome is localized crush injury with systemic manifestations. These systemic effects are caused by a traumatic rhabdomyolysis (muscle breakdown) and the release of potentially toxic muscle cell components and electrolytes into the circulatory system. Crush syndrome can cause local tissue injury, organ dysfunction, and metabolic abnormalities, including acidosis, hyperkalemia, and hypocalcemia.

Previous experience with earthquakes that caused major structural damage has demonstrated that the incidence of crush syndrome is 2-15% with approximately 50% of those with crush syndrome developing acute renal failure and over 50% needing fasciotomy. Of those with renal failure, 50% need dialysis.

Clinical Presentation

Sudden release of a crushed extremity may result in reperfusion syndrome—acute hypovolemia and metabolic abnormalities. This condition may cause lethal cardiac arrhythmias. Further, the sudden release of toxins from necrotic muscle into the circulatory system leads to myoglobinuria, which causes renal failure if untreated.

Hypotension

- Massive third spacing occurs, requiring considerable fluid replacement in the first 24 hours; patients may sequester (third space) >12 L of fluid in the crushed area over a 48-hour period
- Third spacing may lead to secondary complications such as compartment syndrome, which is swelling within a closed anatomical space; compartment syndrome often requires fasciotomy
- Hypotension may also contribute to renal failure

Renal Failure

- Rhabdomyolysis releases myoglobin, potassium, phosphorous, and creatinine into the circulation
- Myoglobinuria may result in renal tubular necrosis if untreated
- Release of electrolytes from ischemic muscles causes metabolic abnormalities

Metabolic Abnormalities

- Calcium flows into muscle cells through leaky membranes, causing systemic hypocalcemia
- Potassium is released from ischemic muscle into systemic circulation, causing hyperkalemia
- Lactic acid is released from ischemic muscle into systemic circulation, causing metabolic acidosis
- Imbalance of potassium and calcium may cause life-threatening cardiac arrhythmias, including cardiac arrest; metabolic acidosis may exacerbate this situation

Secondary Complications

- Compartment syndrome may occur, which will further worsen vascular compromise

Initial Management

Prehospital setting:

- Administer intravenous fluids before releasing the crushed body part. (This step is especially important in cases of prolonged crush [>4 hours]; however, crush syndrome can occur in crush scenarios of <1 hour)
- If this procedure is not possible, consider short-term use of a tourniquet on the affected limb until intravenous (IV) hydration can be initiated

Hospital setting:

Hypotension

- Initiate (or continue) IV hydration—up to 1.5 L/hour

Renal Failure

- Prevent renal failure with appropriate hydration, using IV fluids and mannitol to maintain diuresis of at least 300 cc/hr
- Triage to hemodialysis as needed

Metabolic Abnormalities

- Acidosis: Alkalinization of urine is critical; administer IV sodium bicarbonate until urine pH reaches 6.5 to prevent myoglobin and uric acid deposition in kidneys
- Hyperkalemia/Hypocalcemia: Consider administering the following (adult doses): calcium gluconate 10% 10cc or calcium chloride 10% 5cc IV over 2 minutes; sodium bicarbonate 1 meq/kg IV slow push; regular insulin 5-10 U and D50 1-2 ampules IV bolus; kayexalate 25-50g with sorbitol 20% 100mL PO or PR
- Cardiac Arrhythmias: Monitor for cardiac arrhythmias and cardiac arrest, and treat accordingly

Secondary Complications

- Monitor casualties for compartment syndrome; monitor compartmental pressure if equipment is available; consider emergency fasciotomy for compartment syndrome
- Treat open wounds with antibiotics, tetanus toxoid, and debridement of necrotic tissue
- Apply ice to injured areas and monitor for the 5 P's: pain, pallor, parasthesias, pain with passive movement, and pulselessness
- Observe all crush casualties, even those who look well
- Delays in hydration >12 hours may increase the incidence of renal failure; delayed manifestations of renal failure can occur

Disposition

Patients with acute renal failure may require up to 60 days of dialysis treatment; unless sepsis is present, patients are likely to regain normal kidney function.

BLAST INJURIES

Ear Blast Injuries

Background

Primary blast injury to the organs of the body tends to occur in anatomical succession, depending on the power of the blast and susceptibility of the tissues. The first organ to sustain damage is typically the ear. Despite earlier reports to the contrary, isolated tympanic membrane perforation, without additional signs and symptoms, does not appear to be a marker for occult primary blast injury.

The ear is the most susceptible organ to primary blast injury. Injury to the delicate and sensitive structures of the middle and inner ear represents the most common type of injury after a blast. Blast injury to the ear may result in symptoms of tinnitus, earache, hearing loss, or vertigo.

As highest priority is directed toward diagnosis and treatment of life-threatening injuries, otologic injury is often missed. However, with simple screening protocols, limited management, and appropriate otolaryngologic referral, poor outcome and morbidity can be minimized.

Clinical Presentation

External Ear

- Injury to the external ear is caused most often by flying debris (secondary blast injury)
- Degloving of the cartilage may occur; considered to be a serious injury

Tympanic Membrane (TM)

- The TM is exquisitely sensitive to variations of atmospheric pressure as it functions to transmit minute pressure oscillations encountered by impulsive and continuous sound waves
- Blast overpressure enters the external auditory canal, stretching and displacing the TM medially
- A spectrum of injury may be seen, ranging from intra-tympanic hemorrhage in minor cases to total tympanic membrane perforation in powerful blasts
- Perforations may be unilateral or bilateral, small or complete, and single or double
- The shape of the laceration may be smooth and linear, punched out, or ragged with the edges inverted or everted

Middle Ear

- Disruption of the ossicular chain may occur, especially in larger blasts
- Cholesteatoma within the middle ear and mastoid cavity may occur and are potentially destructive lesions that can erode and destroy important structures of the middle ear, temporal bone, and skull base
- Sequelae of disease can cause conductive and sensorineural hearing loss, vestibular disturbances, cranial nerve palsy, as well as central nervous system complications such as brain abscess and meningitis, making the injury potentially fatal

Inner Ear

- Damage to the auditory and vestibular components of the inner ear may also occur
- The typical blast-injured patient will experience a temporary hearing threshold change; most regain hearing within hours, for others resolution may take days to weeks

Initial Management

- Standard trauma protocols and lifesaving measures should always be addressed first in the assessment and management of the blast patient
- After basic lifesaving measures and severe injuries have been addressed, a focused secondary exam should include otoscopic evaluation of the TM and external auditory canal
- Tympanic membrane injury should raise clinical suspicion and evaluation for additional primary blast injury, but isolated tympanic membrane perforation, without additional signs and symptoms, does not appear to be a marker for occult primary blast injury.

Treatment of External Ear Injuries

- Manage as other soft tissue injuries with attention to foreign body removal, cleaning and irrigation of wounds, and closure
- Cartilage must not be left exposed; wounds should be closed primarily; if the cartilage of the pinna is degloved, it should be buried in the post auricular pouch (may require the expertise of an otolaryngologist or a plastic surgeon)

Treatment of Tympanic Membrane Rupture

- Treatment of TM perforations is typically expectant; if cerumen or blood clots obscure view of the eardrum, these can be carefully suctioned and cleaned by an otolaryngologist
- The ear should be kept clean and dry, and the patient should be referred to a specialist
- Antibiotic eardrops to irrigate and clear the ear of debris or blood clots are indicated for TM perforations or ear canal lacerations

Treatment of Middle and Inner Ear Injuries

- Treatment for middle and inner ear injuries typically can be deferred until an otolaryngologist is available
- Baseline audiometry in all blast-injured patients has been advocated because hearing deficits are common and not always noted by the patient; patients should be followed with interval audiometric evaluation to follow progress during recovery

Disposition

- TM perforations typically have an excellent prognosis with spontaneous resolution in the majority of cases
- For irregular perforations with everted flap, realignment may improve chances of healing; perforations resolve most frequently in the first three months after injury
- Tympanoplasty is indicated if spontaneous resolution is not observed after close observation
- Any TM perforation runs the risk of cholesteatoma formation, especially those perforations that are larger and do not resolve; follow-up is indicated biannually for a minimum of two years

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BLAST INJURIES

Blast Extremity Injuries

Background

The soft tissue and musculoskeletal systems have the highest incidence of bodily injury in survivors of bombings. The most extreme of these injuries, the traumatic amputation, is reported to occur in 1%–3% of blast victims.

Clinical Presentation

Traumatic amputation from ***primary blast injury*** is often considered a marker for a lethal injury. Blast-induced amputations primarily occur through the bony shaft rather than joint disarticulations and may result from the combination of the blast wave and blast wind.

Secondary blast injury to the extremities is marked by penetrating trauma from the bomb casing fragments, materials implanted within the bomb (e.g., nails, screws), flying glass, or from local materials made airborne by proximity to the explosion.

- Wound contamination may occur from the traumatic implantation of biologic material (e.g., bone fragments) from the bomber or from victims in proximity to the explosion
- Irregular projectiles result in extensive tissue damage
- Even with small entrance wounds, surgeons should maintain a low threshold for performing a thorough debridement, as deep contamination and devitalized tissue can produce highly morbid infectious complications

Tertiary and quaternary blast injury to extremities more closely resembles civilian trauma. Victims suffer from blunt impact forces when propelled against surrounding structures.

Building collapse may produce crush injury and the potential for compartment syndrome. (For further information please refer to CDC's "Crush Injury and Crush Syndrome: What Clinicians Need to Know" fact sheet)

Diagnostic Evaluation

- Document a systematic musculoskeletal, neurological, and vascular exam for each extremity
- Extremities should be thoroughly evaluated from a vascular perspective; physical examination is less reliable for detecting vascular injuries from blast than from routine civilian trauma
- Although diligence is warranted in assessing the vascular status of the blast-injured extremity, institutional protocols incorporating mandatory arteriogram have not been published
- Each open wound should be well documented—noting size, exposed bone, and type of contamination—and, ideally, photographed
- Radiological examination of injured extremities should be liberally utilized to identify deep foreign bodies and to characterize bony injuries
- The initial absence of plantar sensation in the blast-injured extremity is not predictive for amputation; 50% of patients will regain this protective sensation over time
- Lower extremity injury scores do not accurately predict the need for amputation

Initial Management

- Even when blast victims have small entrance wounds, surgeons should maintain a low threshold for performing thorough debridement
- All open fractures are considered contaminated and should receive early antibiotic treatment (first generation cephalosporin and/or aminoglycocide, extended spectrum penicillin)
- Obviously contaminated wounds should be irrigated with sterile saline and dressed with iodophore (Betadine)-soaked sponges; once dressed, re-exposure should wait until operative exploration
- Tetanus prophylaxis should be administered unless immunization within five years can be documented
- Extremity fractures should be splinted to provide mechanical stability and relieve pain

Surgical Management

- Initial debridement and bony stabilization should be done in the operating room to preserve life and limb; wounds should be enlarged with extensive longitudinal incisions and debrided in systematic fashion
- The zone of injury will extend well beyond initial skin wounds and fracture sites; aggressive debridement of necrotic and contaminated tissue is critical because there is a tendency to underestimate the soft tissue injury
- Following debridement, low-pressure pulsatile lavage may be employed to thoroughly irrigate the wound
- Bony stabilization is often provided by external fixation with secondary conversion to definitive plate or intramedullary fixation
- When treating vascular injuries, avoiding prosthetic grafts or repairs/reconstruction within contaminated zones of injury is important; where vessels may not be ligated, autologous vein grafts for critical reconstructions should be used
- Following debridement and bony stabilization, soft tissue injury is generally addressed with creation of an antibiotic bead pouch or application of a vacuum wound dressing
- Cultures are generally not useful during this acute injury management
- Repeat debridement is planned every 24–72 hours, depending on the injury extent, until a stable soft tissue bed is attained
- Literature on the management of small, imbedded foreign bodies is limited; it may be the case that small fragments involving soft tissue only, with small wounds and no active infection or gross contamination, may be treated expectantly
- Before and during each operative procedure, limb viability and feasibility of continued efforts to save the limb must be considered; the overall goal is to preserve potentially functional limbs without jeopardizing the patient's overall health

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BLAST INJURIES

Eye Blast Injuries

Background

Ocular injury is a frequent cause of morbidity in terrorist blast victims, occurring in up to 28% of survivors. The eye, with its protective orbit, tarsal plates, and tough sclera, is resistant to traumatic rupture resulting from a blast overpressure wave. Given enough force, however, rupture can occur. Only one case of pure ***primary blast injury*** to the eye has been reported in the literature. Lesser force can result in internal ocular disruption. ***Secondary blast injury***, caused by flying debris or fragments, is a particular threat to exposed and unprotected heads and eyes. Rapidly accelerated sharp particles, large or small, can lacerate or rupture the cornea or sclera and enter the eye.

Glass is a major source of lacerations and foreign bodies (FBs) affecting the eye. Concrete, metal, wood, and other materials from explosions in buildings can create FB eye injuries. Explosions in open spaces tend to accelerate metallic fragments from the bomb and may also propel soil and organic matter. Ocular injuries occurring from terrorist bombs may be extensive, and may involve blunt or penetrating trauma injury to the tissues of the globe, lids, orbit, or ocular adnexa. Frequently, injuries are bilateral and may range from minor corneal abrasions and foreign bodies to extensive eyelid lacerations, open globe injuries, intraocular foreign bodies (IOFB), or orbital fractures.

Clinical Presentation

- Blast eye injuries may present with a wide range of symptoms, from minimal discomfort to severe pain or loss of vision
- It is critical to appreciate that significant eye damage may be present with normal vision and minimal symptoms; these may include eye irritation or pain, foreign body sensation, decreased or altered vision, bleeding, or periorbital swelling or bruising
- Minor blast-related eye injuries include corneal abrasions, conjunctivitis, and superficial foreign bodies
- Open globe injuries, including penetrating and perforating injuries to the cornea or sclera, are the most common serious blast-related eye injuries (up to 20%–50% of those with eye injuries)
- Eyelid lacerations, often extensive, account for 20%–60% of blast-related eye injuries
- Serious non-penetrating eye injuries include hyphema, traumatic cataract, vitreous hemorrhage, retinal detatchment, choroidal rupture, and optic nerve injuries

Diagnostic Evaluation

- Assume all eye injuries harbor a rupture of the globe
- Ruptured globes or IOFBs may be very subtle—signs of a ruptured globe include 360-degree conjunctival hemorrhage; misshapen pupil; brown or pigmented tissue outside the globe; clear, gel-like tissue outside the globe; or abnormally deep or shallow anterior chamber
- Intraocular foreign bodies may be large and obvious, or small and difficult to detect; may be located in any part of the eye

Diagnostic Evaluation (continued)

- Obtain visual acuity of each eye if possible; test for light perception (LP), hand motion (HM), and count fingers (CF)
- Thin-cut computed tomography (CT) of the orbits may be helpful in identifying foreign bodies
- Magnetic resonance imaging (MRI) is contraindicated until it is proven no metallic FBs are present; MRI may be helpful in identifying non-metallic (wood, plastic, organic) foreign bodies

Initial Management

- Do not force the lids open to examine the eye; defer examining the eye if there is massive swelling or hematoma of the lids
- Assume all eye injuries harbor a ruptured globe; do not put any pressure on an eye that may be ruptured
- Do not apply a patch or bandage to the eye—use a convex plastic or metal shield, or the bottom of a clean paper or Styrofoam cup be taped to the surrounding bones to protect the globe
- Do not remove impaled foreign bodies; the distal aspect of the foreign body may be in a location that requires special extraction techniques
- Administer tetanus if warranted
- Administer anti-emetics to reduce nausea and vomiting
- Administer intravenous (IV) broad-spectrum antibiotics if a ruptured globe is suspected; current suggestions include the combination ceftazadime/vancomycin; consider IV clindamycin for dirty soil/organic material-contaminated wounds

Disposition

- The examination of blast victims should be approached with a high level of suspicion for occult eye injuries and a low threshold for referral; consult an ophthalmologist as early as possible
- After initial stabilization of the patient and protection of the eye, rapid transport to facilities with ophthalmic operating room (OR) capabilities should be the main goal

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BLAST INJURIES

Blast Lung Injury

Background

Blast lung injury (BLI) presents unique triage, diagnostic, and management challenges and is a direct consequence of the blast wave from high explosive detonations upon the body. BLI is a major cause of morbidity and mortality for blast victims both at the scene and among initial survivors. The blast wave's impact upon the lung results in tearing, hemorrhage, contusion, and edema with resultant ventilation-perfusion mismatch. BLI is a clinical diagnosis and is characterized by respiratory difficulty and hypoxia, which may occur without obvious external injury to the chest.

Current patterns in worldwide terrorist activity have increased the potential for casualties related to explosions, yet few civilian health care providers in the United States have experience treating patients with explosion-related injuries. Emergency care providers are urged to learn more about the physics of explosions and other types of injuries that can result. Basic clinical information is provided here to inform practitioners of the presentation, evaluation, management, and outcomes of BLIs. Please see the reference list below for more information about how to treat injuries from explosions.

Clinical Presentation

- Symptoms may include dyspnea, hemoptysis, cough, and chest pain.
- Signs may include tachypnea, hypoxia, cyanosis, apnea, wheezing, decreased breath sounds, and hemodynamic instability.
- Associated pathology may include bronchopleural fistula, air emboli, and hemothoraces or pneumothoraces.
- Other injuries may be present.

Diagnostic Evaluation

- Chest radiography is necessary for anyone who is exposed to a blast. A characteristic "butterfly" pattern may be revealed upon x-ray.
- Arterial blood gases, computerized tomography, and doppler technology may be used.
- Most laboratory and diagnostic testing can be conducted per resuscitation protocols and further directed based upon the nature of the explosion (e.g. confined space, fire, prolonged entrapment or extrication, suspected chemical or biologic event, etc).

Photo courtesy of Chest, 1999

Management

- Initial triage, trauma resuscitation, treatment, and transfer should follow standard protocols; however some diagnostic or therapeutic options may be limited in a disaster or mass casualty situation.
- In general, managing BLI is similar to caring for pulmonary contusion, which requires judicious fluid use and administration ensuring tissue perfusion without volume overload.
- Clinical interventions

Management (continued)

- All patients with suspected or confirmed BLI should receive supplemental high flow oxygen sufficient to prevent hypoxemia (delivery may include non-rebreather masks, continuous positive airway pressure, or endotracheal intubation).
- Impending airway compromise, secondary edema, injury, or massive hemoptysis requires immediate intervention to secure the airway. Patients with massive hemoptysis or significant air leaks may benefit from selective bronchus intubation.
- Clinical evidence of or suspicion for a hemothorax or pneumothorax warrants prompt decompression.
- If ventilatory failure is imminent or occurs, patients should be intubated; however, caution should be used in the decision to intubate patients, as mechanical ventilation and positive end pressure may increase the risk of alveolar rupture and air embolism.
- High flow oxygen should be administered if air embolism is suspected, and the patient should be placed in prone, semi-left lateral, or left lateral positions. Patients treated for air emboli should be transferred to a hyperbaric chamber.

Disposition and Outcome

- There are no definitive guidelines for observation, admission, or discharge following emergency department evaluation for patients with possible BLI following an explosion.
- Patients diagnosed with BLI may require complex management and should be admitted to an intensive care unit. Patients with any complaints or findings suspicious for BLI should be observed in the hospital.
- Discharge decisions will also depend upon associated injuries, and other issues related to the event, including the patient's current social situation.
- In general, patients with normal chest radiographs and ABGs, who have no complaints that would suggest BLI, can be considered for discharge after 4-6 hours of observation.
- Data on the short and long-term outcomes of patients with BLI is currently limited. However, in one study conducted on survivors one year post injury, no patients had pulmonary complaints, all had normal physical examinations and chest radiographs, and most had normal lung function tests.

Photo Source: Reprinted by permission from Chest. X-ray Figure I in "Recovery from Blast Lung Injury: One year follow-up", by Hirshberg, Boaz, MD, et al. Dec 1999, Vol 116(6), p 1683-88.

BLAST INJURIES

Blast Lung Injury: An Overview for Prehospital Care Providers

Background

Current patterns in worldwide terrorist activity have increased the potential for casualties related to explosions, yet few civilian emergency medical service providers in the United States have experience treating patients with these injuries. One direct consequence of high-explosive detonations upon the body is blast lung injury—or, BLI. It is characterized by respiratory difficulty and hypoxia. BLI can occur, although rarely, without obvious external chest injury. Persons in enclosed-space explosions or in close proximity to the explosion are at highest risk. BLI presents unique triage, diagnostic, and management challenges.

Clinical Presentation

- Symptoms may include dyspnea, hemoptysis, cough, and chest pain.
- Signs may include tachypnea, hypoxia, cyanosis, apnea, wheezing, decreased breath sounds, and hemodynamic instability.
- Victims with skull fractures, injuries penetrating torso or head, or burns covering more than 10% body surface area (BSA) are more likely to have BLI.
- Hemothoraces or pneumothoraces may occur.
- Due to pulmonary or vascular tearing, air may enter the arterial circulation (air emboli) and result in embolic events involving the central nervous system, retinal arteries, or coronary arteries.
- Clinical evidence of BLI is typically present at the initial evaluation; however, reports show that evidence of BLI can appear 24 to 48 hours after an explosion.
- Other injuries are often present.

Prehospital Management Considerations

- Initial triage, trauma resuscitation, and transport of patients should follow standard protocols for multiple injured patients or mass casualties.
- Explosions in confined spaces result in a higher incidence of primary blast injury, including lung injury. Note the patient's location and the surrounding environment at the time of injury.
- Patients with suspected or confirmed BLI should receive supplemental high-flow oxygen to prevent hypoxemia.
  - A compromised airway requires immediate intervention.
  - If ventilatory failure is imminent or occurs, patients should be intubated; however, prehospital providers must realize that mechanical ventilation and positive pressure may increase the risk of alveolar rupture, pneumothorax, and air embolism in BLI patients.
  - High-flow oxygen should be administered if air embolism is suspected, and the patient should be placed in a prone, semi-left lateral, or left lateral position.
- Clinical evidence or suspicion of a hemothorax or pneumothorax warrants close observation. Chest decompression should be performed for patients clinically presenting with a tension pneumothorax. Close observation is warranted for any patient suspected of BLI who is transported by air.

Blast Lung Injury: Prehospital Care Providers

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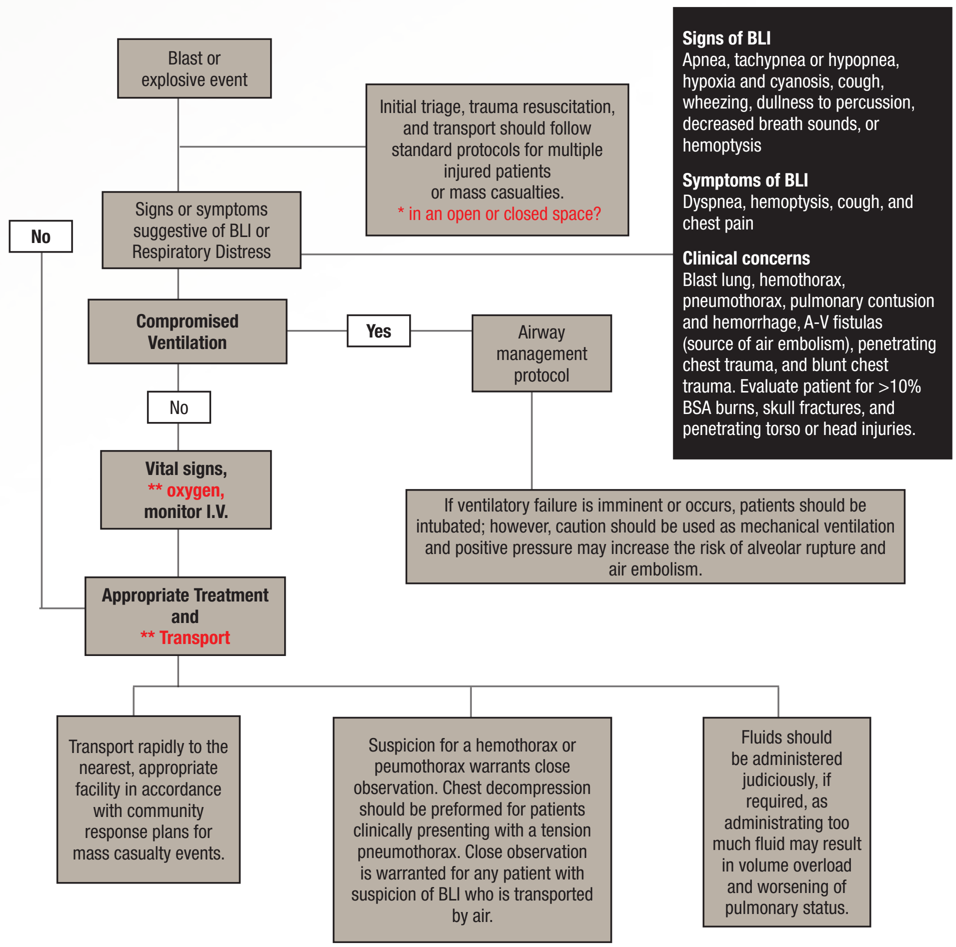
Prehospital Management Considerations (continued)

- Fluids should be administered judiciously, as overzealous fluid administration in the patient with BLI may result in volume overload and worsen pulmonary status.
- Patients with BLI should be transported rapidly to the nearest, appropriate facility, in accordance with community response plans for mass casualty events.

Blast Lung Injury Management Protocol



**There is a higher incidence of BLI in enclosed spaces.*

***High flow oxygen, airway management as appropriate, evaluate for additional injury and rapid transport.*

This fact sheet is part of a series of materials developed by the Centers for Disease Control and Prevention (CDC) on blast injuries. For more information on blast injuries and to order free copies of the blast fact sheets,visit ***http://emergency.cdc.gov/BlastInjuries***

BLAST INJURIES

Bombings and Mental Health

Background

Intentional mass casualty events such as bombings are designed to cause death, destruction, fear, and confusion. In comparison to natural disasters, intentional mass casualty events are associated with higher rates of long term psychological symptoms. The level of fear and distress after a bombing depends on several factors, including injury of self and/or injury or death of family members and friends; separation from or lack of knowledge about loved ones; and the witnessing of horrific and frightening scenes.

Emergency responders and other health care providers may also experience psychological symptoms resulting from continued exposure to death and devastation.

Most fear and distress reactions are normal, expected, and can be managed using principles of good psychological patient care. Clinicians should take all reports of physical, emotional, cognitive, and behavioral reactions seriously.

Clinical Presentation

- Physical reactions: fatigue/exhaustion, gastrointestinal distress, tightening in throat/chest/stomach, headache, worsening chronic conditions, somatic complaints, or racing heartbeat.
- Emotional reactions: depression/sadness, irritability/anger/resentment, anxiety/fear, despair/hopelessness, guilt/self-doubt, unpredictable mood swings, emotional numbness, or inappropriately flat affect.
- Cognitive reactions: confusion/disorganization, recurring dreams or nightmares, preoccupation with the disaster, trouble concentrating/remembering things, difficulty making decisions, questioning spiritual beliefs, disorientation, indecisiveness, worry, shortened attention span, memory loss, unwanted memories, or self-blame.
- Behavioral reactions: sleep problems, crying easily, excessive activity level, increased conflicts with others, hypervigilance/startle reactions, isolation/social withdrawal, distrust, irritability, feeling rejected or abandoned, being distant, judgmental, or over-controlling. Abuse of substances and/or alcohol is also a common symptom.

Initial Management

Provide psychological first aid (PFA) to patients, family members, and emergency response personnel as needed:

- Establish contact and engagement
- Provide/ensure safety and security
- Stabilize, as necessary
- Gather information regarding current needs and concerns
- Avoid encouraging patient to talk about the event as this may intensify symptoms
- Provide practical assistance
- Provide information and education regarding signs of distress and how to cope
- Link with appropriate/needed follow-up services
- Provide family members with accurate, timely, and credible information about patient status and what will be happening next

Bombings and Mental Health

Initial Management (continued)

- Provide family members a quiet location away from distressing signs and sounds
- Minimize separation of pediatric and other patients where separation increases distress
- Optimize services of hospital social services and chaplains

Refer to a behavioral health specialist when the following signs occur:

- Disorientation: inability to know date, location, or recent events
- High anxiety and hyper-arousal: highly agitated, unable to sleep, frequent nightmares, flashbacks, or intrusive thoughts
- Dissociation: emotional disconnection, sense of seeing self from another perspective, seeing the environment as unreal, or time distortion
- Severe depression: hopelessness and despair, unrelenting feelings of worthlessness or guilt, frequent crying for no apparent reason, or withdrawal
- Psychosis: hearing voices, seeing things that are not there, appearing out of touch with reality, or excessive preoccupation with ideas or thoughts
- Inability to care for one self: does not eat or bathe, isolated from others, or unable to manage tasks of daily living
- Suicidal or homicidal thoughts or plans
- Problematic use of alcohol or drugs
- Domestic violence: child, spouse, elder, or animal abuse

Address emergency response personnel concerns as needed:

- Be aware of personal stress vulnerabilities in emergency responders
- Identify physical, emotional, cognitive, and behavioral signs in self and coworkers, and practice self-care
- Enforce breaks
- Use a buddy system to identify stress
- Provide PFA as needed
- Seek help from a mental health specialist if necessary
- Be aware of stress and fears in your family resulting from your work/role

Disposition

- Most fear and distress reactions are normal and will resolve without the intervention of a mental health specialist; however, referral services should be made available to all patients, families, and emergency response personnel
- Individuals who belong to strong social networks, such as families and faith communities, tend to do better than those who do not
- Individuals and families that exhibit continuing signs of distress, and those exhibiting signs of mental illness, including psychosis, severe anxiety, and depression, should be referred to a mental health specialist for ongoing care

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BLAST INJURIES

Treatment of Older Adults

Background

Limited research is available regarding treatment of blast injury in older patients. Nearly all data on the patterns of injury and care of the victims of bombings are not focused specifically on older adults. However, lessons learned from day-to-day trauma and geriatrics care can provide insight into the treatment of blast injuries among older adults, including such considerations as the fact that older patients are especially subject to:

- An increased risk of fractures (e.g., hip, ribs, skull) as a result of decreased elasticity of tissues and organs, in addition to the decreased ability of organs to withstand rapidly applied strain forces;
- Traumatic brain injury; and
- Post-traumatic complications.

Additionally, outcomes are affected by co-morbid conditions, physiologic reserve, multiple concurrent injuries, pre-hospital care, medical/surgical interventions, and rehabilitation services. Some potentially significant co-morbidities include: coronary artery disease, hypertension, chronic obstructive lung disease, diabetes mellitus, dementia, cerebrovascular disease, chronic renal failure, arthritis, gastro-esophageal reflux disease, and anemia of chronic disease. Each of these conditions, along with the medications used for them, need to be taken into account when managing the care of an older blast victim.

Clinical Presentation

- Physiologic derangements in older adults can be occult. They need to be aggressively pursued.
- Physiologic responses to hypovolemia seen in younger patients (e.g., tachycardia, hypotension) may not be seen in the older patients due to medications and preexisting diseases; intravascular volume status of many older adults can be difficult to assess and may require the early use of invasive monitoring.

Diagnostic Evaluation

- The use of standard evaluation and resuscitation protocols (e.g., Advanced Trauma Life Support) is appropriate for initial evaluation and treatment of the older trauma patient.
- Because of natural changes in brain size with aging, older patients can sustain a significant amount of intracranial bleeding from a closed head injury before symptoms of increased intracranial pressure occur; early use of computed tomography (CT) scanning should be considered if head injury is suspected.
- A complete medication history, including use of prescription and non-prescription medications (herbal supplements, etc.), should be obtained and assessed for possible adverse effects and interactions. Commonly prescribed medications in older adults (e.g., beta-blockers, calcium channel blockers) can mask or blunt the normal physiologic response to injury and stress or, in some cases (e.g., warfarin), may exacerbate an individual's injuries.
- Flail chest (particularly anterior) may not be obvious in the older patient, and patients should be thoroughly evaluated for flail chest along with other serious chest injuries. Fractured ribs and/or chest wall contusion can be extremely painful and may be lethal if not managed aggressively.

Diagnostic Evaluation (continued)

- Delirium is not uncommon, and it may be due to medications (including prescription and nonprescription), infections (e.g., pneumonia, urosepsis), or many other medical conditions, including: acute bloodloss, electrolyte imbalance, end organ failure, hypoglycemia or hyperglycemia, hypoxia, arrhythmias, neurological conditions, dehydration, severe pain, immobility, sleep deprivation, fecal impaction, or urinary retention. During initial evaluation, patients with delirium should be assumed to have a reversible etiology until it is proven otherwise.
- Decreased hearing and visual impairment are common in older adults. These conditions need to be evaluated as contributing factors in patients with altered consciousness or cognitive change.

Initial Management

- Pain, which can be manifested as delirium in older adults, should be optimally managed by balancing the need for relief and functional improvement with the potential for adverse events.
- Non-emergent or other non-life-threatening surgical procedures should be delayed for a brief period to maximize physiologic reserve and to manage co-morbidities.
- In the absence of any contraindications, perioperative beta-blocker use is appropriate for patients at high or intermediate risk of cardiac complications if such patients are undergoing emergent, vascular, head and neck, intrathoracic, intraperitoneal, or orthopedic surgery.
- All surgical patients older than age 60 years are considered at high risk of postoperative deep venous thrombosis and should receive prophylaxis.

Disposition

- Social services, rehabilitation medicine, physical therapy, occupational therapy, nutrition, and pharmacology should be consulted early in the hospitalization of older adults, and early mobility should be encouraged post-operatively.
- Family members should be queried regarding existing advanced directives, and health professionals should assist family members in understanding how these directives relate to the specifics of medical care.
- Unrecognized dementia is a risk factor for post-operative delirium.
- Renal function should be determined by creatinine clearance (reduced with increasing age) and not merely by serum creatinine level. Medications that undergo renal excretion may need dosing adjustment when creatinine clearance is less than 60 ml/min.
- Measures to prevent skin breakdown should be evaluated on an ongoing basis.

BLAST INJURIES

Pediatrics

Pediatrics

Background

After a bomb blast or explosion, health care personnel with little or no pediatric experience could be called upon to treat children. Although the general principles of emergency medicine apply when treating explosive-blast victims, all clinicians should understand there are important differences between treating adults and treating infants and children. The highlights of these treatment differences follow below.

Clinical Presentation

- **Brain and Other Neurological Injuries**
  A traumatic brain injury (TBI) can occur without the patient losing consciousness. Consequently, children who appear alert and awake when first examined should be triaged to a hospital if they exhibit any of the following:
  — Abnormal behavior such as irritability or excessive sleepiness
  — Persistent vomiting
  — Seizures
  — Loss of consciousness
  — Evidence of a cerebrospinal fluid leak (CSF) leak

- **Chest Injuries**
  Chest injuries, usually caused by blunt-force impact, are a common cause of death in children subjected to an explosive blast. Several anatomical features unique to children affect their injury patterns. For example:
  — Children have a shorter trachea and so endotracheal intubation is more difficult, and unintentional extubation occurs more commonly.
  — Children have narrower airways and as a result are more prone to bronchospasm and obstruction.
  — Children have much more compliant chest walls; rib fractures are much less common and severe thoracic injuries can occur without significant external evidence of injury.
  — Children have more mobile mediastinal structures. Accordingly, a tension pneumothorax can shift the mediastinum causing respiratory and cardiovascular compromise. Always consider tension pneumothorax in the hypotensive, hypoxic child.

- **Abdominal Injuries**
  Children exhibit many significant anatomical differences from adults with regard to the abdomen. These can affect injury patterns as follows:
  — Children are more prone to abdominal injuries because their smaller and more pliable ribs offer less protection than those in adults.
  — Children have thin abdominal walls that offer them less protection.
  — Children have proportionally larger organs that are more prone to injury.
  — The spleen and liver are the organs most vulnerable to injury from blunt- or penetrating-force trauma.

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Clinical Presentation (continued)

- **Orthopedic Injuries**
  Common orthopedic injuries in children include:
  — Plastic deformity—bowed bone without evidence of cortical disruption.
  — Torus (buckle) fracture—bending of the cortex.
  — Greenstick fracture—fracture of one cortex at the side opposite of force impact.
  — Physeal fracture—involving the physis (growth plate). Physeal fractures represent approximately 18% of pediatric fractures.
  — Forearm fracture—involving radius and ulna and usually occurs after falls.
  — Supracondylar fracture—involving distal humerus and elbow is considered an orthopedic emergency. A careful neurovascular exam is necessary to detect potential damage to the brachial artery.

- **Critical Care**
  Several factors unique to children affect their critical care. These include:
  — Temperature regulation is important because children are more susceptible to heat loss by radiation, convection, and evaporation.
  — Young children have relatively large heads with immature neck musculature. This makes them more susceptible to cervical spine injury caused by the fulcrum effect in the C1–C3 area.
  — Children under age 8 years also are susceptible to SCIWORA (spinal cord injury without radiographic abnormality).
  — Traumatic asphyxia occurs almost exclusively in children. It results from sudden compression of the abdomen or chest against a closed glottis. Treatment is supportive. Symptoms of traumatic asphyxia include:
    - Hyperemic sclera
    - Seizures
    - Disorientation
    - Petechiae in upper body
    - Respiratory failure

Initial Management

- Consider possible cervical spine injury in children with head injury.
- Repeat examinations are essential because young children often are not able to cooperate with their initial examiner.
- Children have a remarkable cardiovascular reserve; even minimal signs of shock will not occur until 25% of blood volume is lost. Recommended initial fluid resuscitation is 20–30 cc/kg of normal saline or Ringer's lactate.

Other Considerations

- Decontaminate children in the presence of parents whenever possible to minimize disruption and reduce the possibility of separation anxiety.
- Mental health issues are common in children who have experienced a traumatic event such as a bomb blast. If parents are accessible, provide them with mental health referral sources.
- For further information on psychological first aid for children and families, please refer to CDC's fact sheet "Blast Injuries: Bombings and Mental Health."

BLAST INJURIES

Post Exposure Prophylaxis for Bloodborne Pathogens

Background

Victims presenting from the scene of an explosive event, as well as those participating in recovery and transport efforts, including first responders, are at risk of exposure to bloodborne pathogens via body fluids and foreign bodies such as bone, contaminated weapon fragments, or other debris. For victims near the scene of an explosive event, biological foreign bodies such as bone can become projectiles that contribute to the spectrum of blast injury.

As noted in the U.S. Public Health Service guidelines for occupational exposure of health care workers, exposure to blood and other body fluids increases the risk of exposure to hepatitis B virus (HBV), hepatitis C virus (HCV), and human immunodeficiency virus (HIV).

Clinical Presentation

Individuals presenting from the scene of a bombing can subsequently be categorized into one of three major risk categories for exposure to blood or bodily fluids:

Category 1. Penetrating injuries or nonintact skin exposures

Category 2. Mucous membrane exposures

Category 3. Superficial intact skin exposures without mucous membrane involvement

Initial Management

- HBV post exposure prophylaxis (PEP) is recommended for individuals presenting from the scene with nonintact skin or mucous membrane exposure (Categories 1 and 2). The hepatitis B vaccination series (age-appropriate dose and schedule) should be initiated as soon as possible, preferably within 24 hours and not later than 7 days after exposure. The vaccine should be administered to those who:
  - Lack a reliable history of immunization against HBV; and
  - Have no previous history of contraindication to immunization against HBV.
- There is no prophylaxis recommended for HCV. Consider testing (immediately or during follow-up referral) if exposure is to a known or likely HCV-infected source or multiple sources. If testing is performed, obtain baseline (within 7–14 days) and follow-up (4–6 months) anti-HCV and ALT (Category 1; generally no action for Category 2).
- Generally, no PEP is warranted for HIV—consider action ONLY if exposure is to a known or highly likely HIV-infected source (Categories 1 and 2).
- No PEP or testing is recommended for those individuals presenting from the scene with possible superficial skin exposure (Category 3).

See Table 1 for summary.

Table 1. Recommended post exposure management by risk category and specific pathogen

Risk Category	HBV	HCV	HIV
Category 1.	INTERVENE	CONSIDER TESTING	GENERALLY NO ACTION
Category 2.	INTERVENE	GENERALLY NO ACTION	GENERALLY NO ACTION
Category 3.	NO ACTION	NO ACTION	NO ACTION

Special Considerations regarding PEP Recommendations

Consultation from health care specialists knowledgeable about HBV, HCV, and HIV is ideal, in particular for pediatric patients and pregnant women. Health care professionals should be knowledgeable about consulting existing guidelines and recommendations regarding contraindications and precautions, counseling and education, testing, medical follow-up and, if PEP is initiated, management of adverse events. In addition, it should be recognized that following these recommendations in response to a mass casualty event could create a hepatitis vaccine demand that exceeds local resources.

Special Considerations regarding HIV PEP Recommendations

- HIV PEP should be rarely indicated; if it is indicated, start as soon as possible after exposure
- If indicated, do not delay PEP for HIV test results
- Collect specimens for baseline testing: HIV, CBC, LFTs, creatinine, pregnancy test
- Test in accordance with applicable state/local laws
- Consult experts: local infectious disease, hospital epidemiology, or occupational health consultant; local, state, or federal public health authorities
- PEPline 24-hours/day: 888-448-4911 (preferred) or http://www.ucsf.edu/hivcntr/Hotlines/PEPline.html Or HIV/AIDS Rx information service http://aidsinfo.nih.gov
- Continue for 4 weeks
- Discharge with written information, a 5–7 day supply of medication, and a follow-up appointment
- HIV specialist should reassess within 72 hours

BLAST INJURIES

Prehospital Care

Background

Because a terrorist bombing can cause a large number of seriously injured persons, prehospital care systems play a critical role in managing the emergency medical response to this kind of mass casualty event. The quality of prehospital emergency medical response will affect the quality of all subsequent clinical care activities, and it may directly affect patient mortality and morbidity rates. The complexity and scope of a mass casualty event caused by an explosion requires that prehospital emergency medical care systems address the following issues:

- Recognition of specific hazards associated with a terrorist bombing, such as secondary devices, environmental hazards (e.g., toxins, fires) and structural instability.
- Identification patients with significant blast related injuries.
- Effective communication with acute care medical resources and emergency management resources.
- Expedient patient triage to match available resources with patient needs.

In the United States, the majority of emergency medical service (EMS) systems are organized and coordinated at the local level. Nationwide, this results in an incredibly diverse prehospital emergency medical care system that is often markedly different in operational and clinical approaches among jurisdictions. According to the Institute of Medicine, EMS systems are challenged by the following key issues: insufficient coordination, response time disparities, inconsistent quality of care, lack of disaster readiness, divided professional identity, and limited evidence base for the profession.

Even though it faces these challenges, the prehospital medical care system will play a pivotal role in blast event medical management by identification and transport of patients with potentially significant injuries to appropriate trauma centers, and direction of less injured patients to other medical facilities.

Challenges for EMS Providers

Numerous challenges and potential concerns must be addressed by EMS providers.

- Blast sites are dangerous; EMS personnel must be safety conscious and alert for hazards such as:
  - secondary device explosions; and
  - fire, environmental exposure, or structural collapse.
- Exhaustive prehospital evaluations of survivors are impractical due to limited resources and potential dangers at the bombing scene.
- Patients with mild to moderate injuries may rapidly move on their own from the explosion site to the closest hospital(s).
- Effective prehospital triage is an essential component of medical management for an explosive event.
- Due to infrequent occurrence and the diversity of blast events, rigorous study of triage methodologies is difficult.
- A nationally standardized triage methodology does not currently exist.

Challenges for EMS Providers (continued)

- Prehospital medical responders have adopted a variety of commercially available and locally created methodologies, many of which possess similar processes and definitions; however, subtle differences among them may cause confusion during a chaotic situation.
- Overtriage may deplete limited resources, thus degrading patient care and increasing mortality rates of those critically injured.

Improving Prehospital Care After Blast Events

In the absence of a defined national prehospital triage methodology, agencies with responsibility for triage at mass casualty events should make every effort to standardize processes and definitions at the local level. An effective prehospital triage system includes:

- common terminology and processes;
- easily understood protocols for providers with varying amounts of medical education;
- deployable tools and record keeping instruments for apparatus possibly used during an emergency response; and
- functional exercises where prehospital medical providers demonstrate understanding of emergency response processes and definitions.

Effective management of the emergency medical response to a mass casualty bombing requires substantial preparation by prehospital medical care systems. Integration into the local trauma system and understanding its emergency response methodology are critically important to ensuring that the most severely injured bombing victims are transported to facilities that have the resources required to care for them. Prehospital medical system administrators should focus on:

- facilitating interagency collaboration by standardizing command structure, lines of communication, and triage methodology.
- ensuring that prehospital medical care providers have a basic understanding of blast pathophysiology and the complex injury patterns produced by such an event.
- training prehospital medical providers to recognize external signs of significant blast injury and designing triage guidelines that facilitates moving these patients to the highest level trauma center(s) in the local system.

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BLAST INJURIES

Radiological Dispersal Devices and Radiation Injury

Background

Radiological Dispersal Devices (RDDs) or "dirty bombs" consist of radioactive material combined with conventional explosives. Their force is so powerful they can disperse such material over an area as large as multiple city blocks. People in the immediate area may be killed or injured initially from the effects of the blast and not from radioactivity. RDDs are primarily used to produce psychological rather than physical harm by inducing panic and terror in the target population. The clinical presentation of exposed casualties will mostly resemble conventional injuries. This is because the clinical effects of all but the most severe radiation exposures are delayed.

A survey conducted with specialized radiological equipment is the only way to confirm the presence of radiation. If radioactive material is used in a terrorist bombing, victims must be assessed for both exposure and contamination. People exposed to radiation can suffer radiation illness if their dose is high enough, but they do not become radioactive. Contamination occurs externally when loose particles of radioactive material are deposited on surfaces, skin, or clothing. Internal contamination occurs when radioactive particles are inhaled, ingested, or lodged in an open wound. Contaminated patients should be decontaminated as soon as possible after being treated for life-threatening injuries. The radioactivity levels of contaminated patients should not pose a health risk to care providers. Guidelines for protection and treatment are provided below.

Triage and Staff Protection

- Establish an ad hoc triage area in a location based on the hospital's disaster plan and the anticipated number of casualties. Stock a sufficient quantity of hospital-supplied gowns to replace contaminated clothing.
- Establish both a contaminated area and a clean area and separate them by a buffer zone.
- Remove contaminated outer garments when leaving the contaminated area.
- Using a radiation meter, survey the bodies of persons when they exit a contaminated area.
- Follow standard guidelines for protection from microbiological contamination.
- Ensure surgical masks are adequate; N95 masks, if available, are recommended.
- Survey hands and clothing with a radiation meter at frequent intervals.

Decontaminating the Injured

- Survey the patient with a radiation meter using a consistent technique and trained personnel.
- Note exceptionally large amounts of surface or imbedded radioactive material.
- Handle easily-removable radioactive objects with forceps and store them in lead containers.
- Use a standardized form to record location and level of any contamination found.
- Remove patient clothing by carefully cutting and rolling it away from the face toward the feet to contain the contamination.
- Double-bag clothing using radioactive hazardous waste guidelines and then label the bag.
- Repeat the patient survey and record contamination levels.
- Wash wounds with saline or warm water first. Gently cleanse intact skin with soap and water, starting outside the contaminated area and washing inward; do not irritate or abrade.
- Flush eyes, nose, and ears, and rinse mouth if facial contamination occurred.
- Survey and note radiation level again; repeat washing until survey indicates radiation level is no more than twice the background or the level remains unchanged.

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Decontaminating the Injured (continued)

- Cover wounds with waterproof dressing.
- For mass casualties, consider establishing separate shower areas for ambulatory and non-ambulatory patients.

Diagnosis and Treatment

- Perform sequential CBCs with differential to assess declines in lymphocyte levels.
- Monitor for fluid and electrolyte balance and for evidence of hemodynamic instability.
- Treat symptomatically and focus on preventing infection; use antibiotics.
- Consider cytokines, e.g., Neupogen® and hematopoietic growth factors.
- Perform surgical interventions within 48 hours or delay them until after hematopoietic recovery.

Radiation-related Illness/Injury

Acute Radiation Syndrome (ARS) is caused by high doses of radiation that are rapidly delivered to large portions of the body. A dirty bomb will likely generate low levels of radiation exposure.

Symptoms can be immediate or delayed, mild or severe, based on radiation dose.

- Nausea or vomiting may occur minutes to days after exposure. The rapid onset of vomiting is a major factor in diagnosis and dose estimation of radiation.
- Early onset of vomiting followed by symptoms of bone marrow suppression, gastrointestinal destruction, and cardiovascular/central nervous system effects are signs of acute illness.
- Depending on the stage of illness, a patient may be asymptomatic.

Cutaneous Radiation Injury is acute radiation injury to the skin.

- Transient itching, tingling, erythema, or edema may be seen within hours or days, and is usually followed by a latent period; lesions may not be seen for weeks to months post exposure.
- The delay in occurrence differentiates these lesions from thermal burns.
- Treat localized injuries symptomatically, focusing on pain and infection control.

Internal Contamination should be considered if persistently high survey readings are noted following decontamination. It generally does not cause early symptoms. Nose or mouth contamination may indicate inhalation or ingestion.

- Assessment may include analyzing urine, blood, and fecal samples or whole body counts.
- Radiation experts may recommend early administration of radionuclide-specific decorporation agents such as Prussian Blue, DTPA, or Bicarbonate.
- Gastric lavage, antacids, and cathartics assist in clearing ingested contaminants.

Psychosocial Issues

- In urban areas, hundreds to thousands may seek care. Many may seek radiological screening, many will need decontamination, and many will simply seek reassurance.
- Psychogenic illness symptoms, such as nausea or vomiting, may manifest.
- Vomiting due to radiation exposure is usually recurrent rather than episodic.
- Include mental health professionals on the response team.

This fact sheet is part of a series of materials developed by the Centers for Disease Control and Prevention (CDC) on blast injuries. For more information on blast injuries and to order free copies of the blast fact sheets, visit ***http://emergency.cdc.gov/BlastInjuries***

For more information about radiation emergencies, visit: ***www.bt.cdc.gov/radiation.***

BLAST INJURIES

Radiological Diagnosis

Background

Explosive events have the potential to inflict numerous casualties with multiple injuries. The complexity of this scenario is exacerbated by the fact that few providers or medical facilities have experience with mass casualty events in which human and material resources can be rapidly overwhelmed. One significant difference between explosion-related injury and other injury mechanisms are the number of patients and multiplicity of injuries which require a higher allocation of resources. With this caveat, the appropriate utilization of radiology resources has the potential to impact in-hospital diagnosis and triage and is an essential element in the optimizing the management of the explosive injured patient.

Initial Evaluation

Primary Blast Injury is caused by the overpressure blast wave produced by high-order explosives, primarily affecting air-filled organs and cavities such as the ear, lung, and abdomen. This blast wave is magnified by the reflection of surfaces as seen in closed-space explosions (e.g., inside a building, bus, train).

Radiological diagnosis of **primary blast injury** focuses on pulmonary and enteric barotrauma. Pulmonary barotrauma is characterized by pulmonary opacification secondary to diffuse pulmonary alveolar hemorrhage and pneumothorax.

- Patients with substantial pulmonary blast injury often present with significant pulmonary symptoms which may include dyspnea, tachypnea, and cyanosis. A chest radiograph is a confirmatory test.
- In the absence of peritonitis or clinical signs, the role of radiological studies in assessing primary blast injuries is to identify enteric injury manifesting as intraperitoneal free air. Computerized tomography (CT) has a much greater sensitivity for the detection of intraperitoneal free air than does conventional radiography.

Secondary Blast Injury is characterized by trauma due to impact from bomb fragments, to include the casing of the bomb in addition to objects added to the device to increase lethality (e.g., screws, nails, nuts and bolts). It can also result from debris external to the bomb that is secondarily propelled by the explosion. Secondary blast injury primarily causes penetrating trauma, but may also cause blunt trauma. Patients can sustain penetration of any region of the body, and typically have fragment penetrations in multiple body regions.

Radiological diagnosis of **secondary blast injury** helps to prioritize treatment by identifying life-threatening injury that may require timely intervention. For example, radiological imaging can be used as follows:

- Portable biplanar x-ray can be used to define basic penetration patterns.
- Conventional x-ray can be used to identify patients with fragment wounds suspicious for causing intracavitary injury, who then will require more advance methods of imaging. (Conventional x-ray is not sensitive for body cavity penetration.)
- The thoracoabdominal CT scan can be used to identify unapparent injuries, including among hemodynamically stable patients with blast fragment penetrations.
- The CT scan can be used to identify patients injured by fragments who do not need surgical therapy.

Initial Evaluation (continued)

Tertiary blast injury results from the victim being thrown by the force of the blast wind. These injuries primarily involve blunt trauma, but may also be classified as penetrating trauma (e.g., impalement on sharp object).

Radiological evaluation of **tertiary blast injury** primarily focuses on identifying fractures, but also includes the detection of other injuries. For example:

- Plain films are useful in evaluating the thorax for signs of pneumothorax, hemothorax, or pulmonary contusion, as well as stigmata consistent with acute thoracic aortic injury.
- Pelvic radiography is used to exclude or to determine the morphology of pelvis fractures.
- Focused abdominal sonogram for trauma (FAST) can be used to rapidly diagnose the presence of intraperitoneal fluid in patients with blunt-force trauma injuries. In explosive events, this fluid is presumed to be blood.
- Similar to the diagnostic algorithm for the secondary blast injury, the CT scan is both sensitive and specific for determining traumatic pathology.

Summary and Disposition

The severity and diversity of injuries caused by explosions provide treatment challenges for emergency medical providers.

- Due to the potential for surge and nearby hospitals following an explosion, effective use of radiology resources is vitally important during patient triage and in identification of patients with the greatest need of life-and-limb saving interventions.
- If radiography resources permit, imaging should be used liberally in the acute diagnostic phase to increase the accuracy of diagnosis and enhance treatment.

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BLAST INJURIES

Thermal Injuries

Background

Thermal injuries from explosions of conventional weapons are classified as quaternary blast injuries. The rapidly expanding fireball from the explosion may cause flash burns over exposed body parts (e.g., hands, neck, and head). Confined space explosions can enhance thermal effects and increase the risk of inhalation injury. Effectively managing thermal injuries associated with primary blast injury, particularly blast lung injury, may be challenging due to conflicting fluid requirements.

Clinical Presentation

- Most bomb-related burns cover <20% of the total body surface area (TBSA), but occur in combination with other blast injuries.
- Inhalation injury is relatively common (18%) among those who survive explosions in confined spaces.

Initial Prehospital Management

- Stop the burning process; remove restrictive and smoldering clothing.
- Rapidly cooling the isolated burn (cool water irrigation, no ice) will reduce the zone of stasis associated with initial thermal injury; avoid hypothermia and freezing tissue.
- Apply simple dressings to limit secondary wound contamination.

Initial Hospital Management

Immediate Steps

- Remove restrictive and smoldering clothing to stop burning, allow for a thorough examination, and prevent secondary fires in the presence of high flow oxygen.
- Irrigate thermal injuries with cool water to help reduce the area contained in the zone of stasis. Injuries in this area are potentially reversible. Do not use ice and be cognizant of the potential for hypothermia.

Airway/Inhalation Injuries

- Inhalation injury can result from the explosion's extinction of available oxygen and creation of particulate matter, smoke, superheated gases, and toxic by-products.
- Suspect an inhalation injury with a:
  - Closed space explosion;
  - Singed nasal vibrissae or carbonaceous sputum; or
  - Elevated CO or CN levels (obtain only if victim numbers are low— indiscriminant ordering will overwhelm the laboratory resources).
- If airway injury exists, intubate early. Inhalation injury can be fatal if a patient's airway is blocked due to mucosal swelling and progressive edema that obliterates normal airway structures.

Thermal Injuries

Initial Hospital Management (continued)

- At admission, consider evaluating the fiber optic airway to determine if subsequent airway intervention or aggressive pulmonary toilet is needed.
- Among patients with primary blast injury to the lung, mechanical ventilation and positive pressure may increase the risk of alveolar rupture and air embolism. Patients with inhalational injury may be at a higher risk of barotrauma.

Fluid Resuscitation

- Fluid resuscitation is required for victims with burns that cover >15% of TBSA.
- The goal is to replace the loss of intravascular volume and to maintain tissue perfusion in the first 48 hours post-injury, when capillary leak and relative hypovolemia occur.
- Inadequate fluid resuscitation increases morbidity and mortality.
- Fluid resuscitation for significant thermal injury that is initiated more than four hours post-injury is associated with almost 100% mortality.
- Give Lactated Ringers (LR):
  - 4cc/kg/%TBSA in the first 24 hours
  - Give half in the first eight hours starting from the time of the burn insult itself, and the remaining half during the next 16 hours.
- Effective fluid resuscitation is demonstrated by adequate urine output.
- Take care when treating burn victims who have also suffered a blast lung injury. The risk of aggressive hydration to the blast injured lung must be balanced with the need to provide IV fluids to manage the burn.

Pain Management

- Give narcotics for pain.
- Recognize when resources may be limited (e.g., a Rhode Island nightclub fire exhausted a three-month narcotic supply during the acute resuscitation phase at a Level I trauma and burn center).

Other Considerations

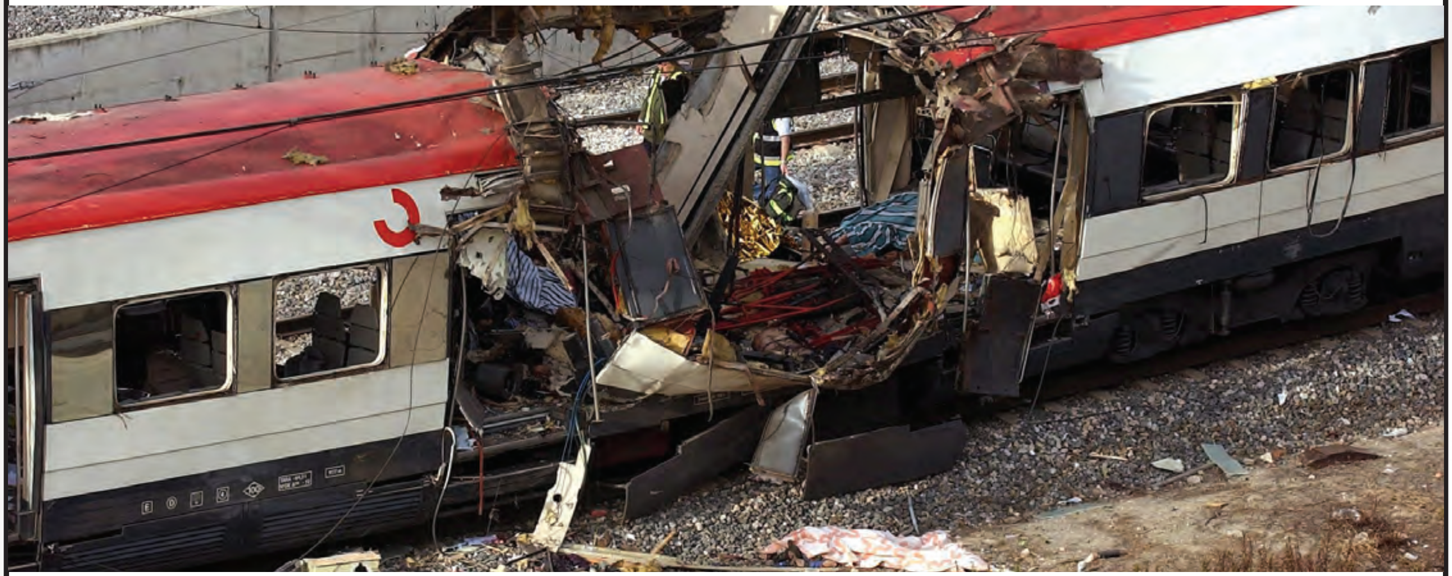
- Administer tetanus toxoid if patient did not receive a booster in the last five years, or if date of booster is unknown.
- Full-thickness burns of thorax and extremities may cause the constriction of underlying structures and require an escharotomy.

Disposition

- Inhalation injury is an independent predictor of prolonged ICU care and mortality.
- Burns covering >30% of TBSA are associated with increased death rates.
- Death from burns is dependent on: the percentage of TBSA affected, presence or absence of significant airway and lung involvement, and the age of the victim.
- Patients diagnosed with primary blast lung injury should be admitted to the hospital, regardless of the extent of any associated burn.

This fact sheet is part of a series of materials developed by the Centers for Disease Control and Prevention (CDC) on blast injuries. For more information on blast injuries and to order free copies of the blast fact sheets, visit ***http://emergency.cdc.gov/BlastInjuries***

Free Blast Injury Products Available!



BOMBINGS:

INJURY PATTERNS AND CARE INTERACTIVE

Scenario-based Training 2.0

This course focuses on the effects of explosive events and provides the latest clinical information regarding blast-related injuries from terrorism. It was developed to compliment all hazards disaster response training programs and also serve as an independent training source for emergency responders and hospital staff.

The interactive scenario-based training includes:

- Sixty minutes of instruction
- Practice scenarios and assessment situations with feedback used to provide context and realism
- Visuals of several types including photos of actual blast events with patients, photos taken specifically for the training, charts, and diagrams
- Final exam

The interactive scenario-based training, as well as curriculum guides and PowerPoint presentations for one and three hour courses (CE and CECBEMS accredited), and the quick reference pocket guide are available free of charge at: http://emergency.cdc.gov/BlastInjuries

Available Online Soon

Bombings Injury Patterns and Care: System Preparedness Course 1.0

This course is designed to assist system administrators including public safety, healthcare, public health, emergency management) and leadership in their preparation and response to terrorist bombings. The principles outlined in this course, while focused on bombings, can be translated to any crisis or disaster. Specifically, this course:

- Discusses challenges to effective preparedness
- Proposes solutions to systems preparedness
- Reviews current resources available for preparedness and response

Developed under the Terrorism Injuries: Information, Dissemination, & Exchange (TIIDE) partnership agreement in with American Trauma Society, this course focuses on the core competencies in effective leadership and crisis management, challenge recognition, systems approach to preparedness, and best practices for saving lives in the event of terrorist bombings.

Helping all people live to their full potential

For more information on blast injuries
and to order free copies of the blast fact sheets,
visit http://www.emergency.cdc.gov/blastinjuries

Centers for Disease Control and Prevention
National Center for Injury Prevention and Control
Division of Injury Response

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