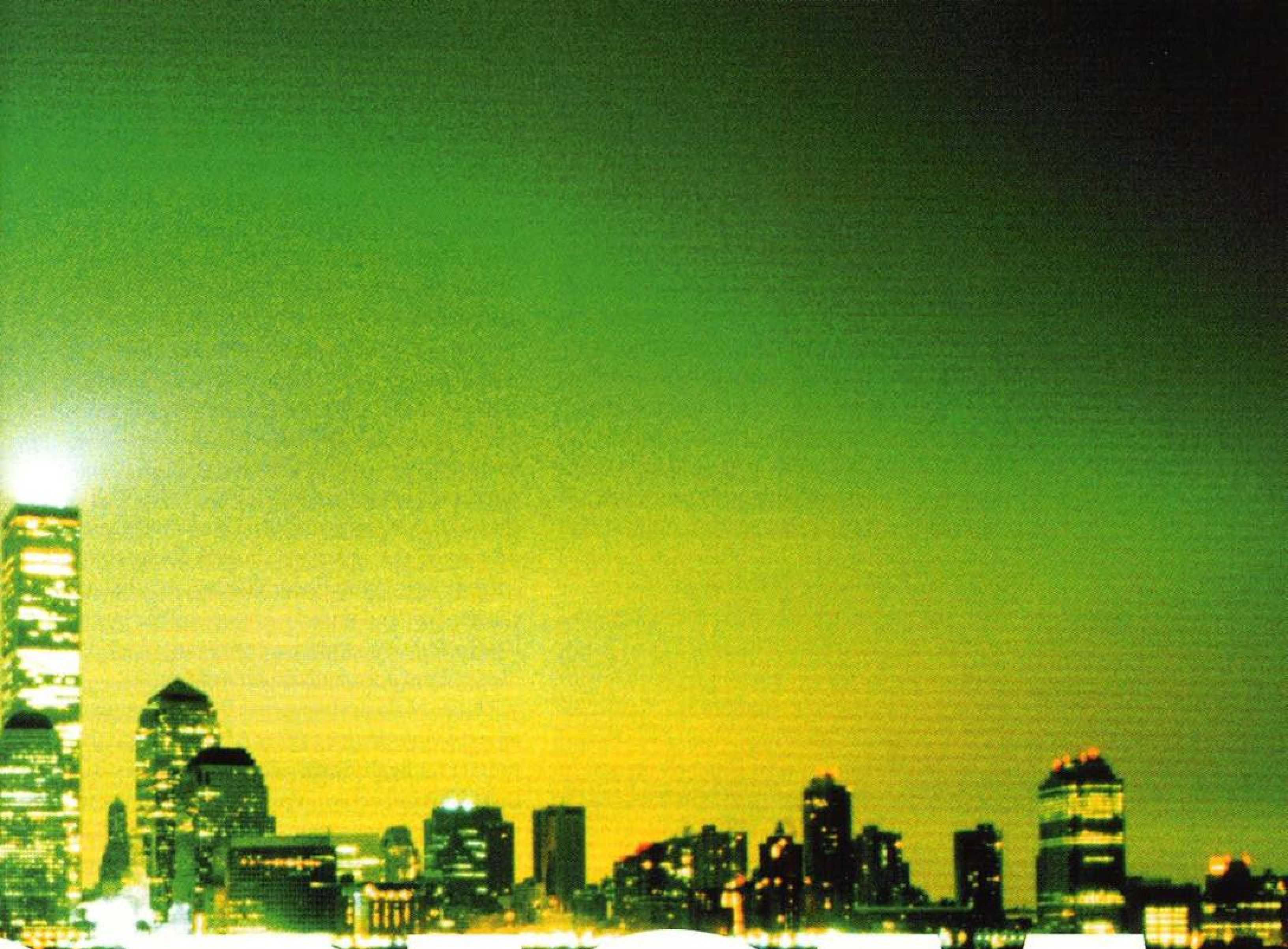
Kenneth W M Warnock, CST

TERRO
AND ITS IMPACT ON THE

As evidenced on September 11, 2001, the United States is not immune to acts of terror. This event marks one of the first occasions that foreign parties acted against American citizens on American soil. In the aftermath of this horrific attack, we, as professionals within the surgical setting, must



RISM
PRACTICE OF SURGERY

review our personal and institutional preparedness for such events. This article will discuss potential types of attack using explosive weapons, their impact on surgical practice, and control and response strategies used to minimize the associated morbidity and mortality.

Weapons of mass destruction

The act of flying a fuel-laden jet into a skyscraper proved a relatively simple task, as was tragically demonstrated in New York and Washington, DC. This type of terrorism has the potential to create massive disruption in the delivery of health care services both at the scene and at local hospitals. In addition, this kind of terrorist act has the potential of causing thousands of traumatic injuries in relatively small areas, stressing the infrastructure of local and regional health care systems. Many of the injuries identified in this type of situation will require surgical intervention and many will ultimately prove fatal.[1,2,3]

Weapons of mass destruction (WMD) fall into several categories. Incendiary (or thermal) weapons are devices designed to explode or ignite (eg, nuclear weapons). Biological weapons contain microorganisms designed to transmit disease. Chemical weapons contain various substances created to harass and incapacitate their victims, and fall into several classes: blister agents, choking agents and nerve agents. In response to September 11, this article focuses primarily on conventional (non-nuclear) incendiary weapons.

WMD Design

The two common types of conventional thermal WMDs are composed of solid matter, volatile liquids, or a composite of both. Solid matter devices are generally easier to transport and position and have the potential of causing greater destruction. Liquid and composite devices usually require larger quantities of the agent, and therefore are not practical to assemble, store or transport. Composite weapons may be safer to produce and transport, as these weapons require both the solid and liquid to be mixed prior to becoming explosive. The terrorist may be able to affix a timing device to regulate the mixing of the two components and be far away when the subsequent explosion occurs.

Each of these devices relies on rapid ignition resulting in an almost instantaneous reaction of their chemical components.[4] This rapid reaction reduces the opportunity for potential victims to escape. The destructive nature of these weapons, when applied against humans, causes significant impact to the local health care infrastructure.[5]

Impact

Most acts of terror to date have involved explosive or incendiary devices. The act of detonating or igniting a device of this nature serves the needs of terrorists and hate-mongers in several ways. First, these devices are relatively easy to produce and conceal and are the least expensive of terrorist tools. Second, the impact of these devices is sudden and intense, creating an atmosphere of chaos that terrorists crave. Third, although these incidents affect a relatively small geographical area, the psychological impact on citizens' well-being extends far beyond the site, causing fear and uncertainty among the populace. In addition, explosive devices are accompanied by loud noise and concurrent fire.

Unlike biological weapons, the detonation of an explosive device causes a sudden, massive impact on health care personnel and institutions. This impact is multiplied when health care providers become victims, as in the World Trade Center disaster. Chemical weapons produce a significant impact on emergency medical services, firefighters and law enforcement personnel. Casualties from a chemical weapon release usually only require stabilizing treatments provided in the field and in the emergency department.[6] Some of these patients will require inpatient observation or intensive care unit (ICU) support; however, very few will require surgical intervention. Therefore, the effect of a chemical attack on a civilian target is not a major threat to the operation of the surgical services department.

Similarly, a biological attack will have very little bearing on the operating room setting. Victims of a biological agent release will develop symptoms 12 hours to several weeks after the actual exposure. Most organisms identified by the Centers for Disease Control and Prevention (CDC) as likely bioterrorist agents will cause the victims to experience symptoms within 24 hours to one week.[6,7,8] These individuals will primarily present to physicians' offices, clinics and hospital emergency departments. The patient load from this type of attack will be staggered and unlikely to overwhelm most hospital-based resources initially. In any case, victims of bioterrorism are not surgical patients, per se, and the physical impact on the surgical environment will be minimal.[9]

The greatest effect on and demand for surgical resources will be from terrorist acts involving incendiary devices. Impact on the operating room at the affected hospital(s) will vary based on the type of device used, time of day or night, physical space involved in the attack and number of casualties. For example, a bomb exploding in the lobby of a large office building at 3 pm will have a significantly greater impact on local hospitals than if the explosion took place at 3 am. All JCAHO-accredited hospitals have written disaster plans that outline procedures to follow during such an attack. These plans should be implemented as soon as personnel become aware that an explosion has occurred in the vicinity, regardless of the time of day or night.

Mechanisms of injury

Injuries associated with explosions are related to the proximity of the victim to the detonation and the related physical properties of the location.[10] Individuals in proximity to the explosion suffer injuries known as "blast injuries." Injuries vary depending on where the explosion occurred (eg, within an enclosed structure or on the street). These injuries occur as a result of the detonation velocity and the displacement of the normal air volume (pressure) that occupies the given space. This displacement is caused by the sudden changes in atmospheric pressure within a given space. The force of the air displacement is referred to as the "shock wave," or blast overpressure (BOP), and is responsible for much of the damage and many of the injuries associated with an explosion.[4,10,11,12] Injuries associated with an explosive detonation are classified in Table 1.

Severity of injuries depend on the size of explosion and the distance from detonation. An additional concern is whether the victim was inside an enclosed structure or on open ground.

One final note: manufactured explosive devices often incorporate nails, screws or other metal fragments to increase the number and severity of injuries and damage.

The physics of an explosion

The detonation of an explosive device produces an initial pressure wave that progresses outward from the detonation point at supersonic speed (>2,000 m/sec) and quickly deteriorates.[1,10] An explosion that occurs outside produces a pressure wave known as a free-field or Friedlander wave (Figure 1a). Explosions within an enclosure produce a more complex wave form (Figure 1b). This complex wave has multiple spikes and

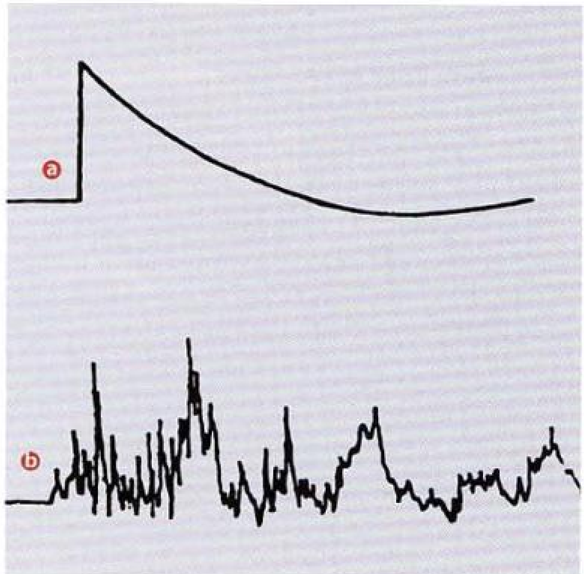


FIGURE 1

a Free-field Friedlander wave[12]

b Complex wave.[12]

depressions caused by the reflection of BOP from walls and ceilings. The pressure wave diminishes at a rate of the cubed root of the distance from the explosion. Therefore, a victim standing 10 feet (3 m) from the explosion will be subjected to nine times the amount of force than that of a person standing 20 feet (6 m) from detonation.[10]

This force may be strong enough to distort or destroy walls, ceilings and floors causing major structural damage that impedes initial rescue efforts. Delays in rescue increase morbidity and mortality of victims. Walls and other flat surfaces reflect the blast wave and consequently, injuries suffered within enclosed space explosions are

Table 1 **Classifications of Blast Injuries**

Primary blast injuries—These are injuries that are directly related to the effect of the shock (pressure) wave on the body.

Secondary blast injuries—These are injuries that result from debris or shrapnel that has become airborne as a result of the explosion.

Tertiary blast injuries—Tertiary injuries occur when a person is lifted by the shock wave and propelled into another person or physical structure.

Miscellaneous blast injuries—This type of injury is an indirect result of the explosion and includes burns, inhalation injuries and crushing injuries suffered from collapsing walls, floors or ceilings.[1,2,12,13,14]

more frequent and catastrophic than explosions that occur in open air.

During an explosion, an exothermic reaction occurs releasing tremendous amounts of energy resulting in burns from the intense heat. Additionally, the energy generated by the explosion may be sufficient to cause combustion of inanimate objects in the area. Victims in the area of combustibles are also likely to suffer thermal injuries as well as smoke inhalation as a result of the conflagration.

Patient load and assessment

The anticipated patient load depends on the severity of the event and the overall number of casualties. The operating room as well as the entire health care facility must anticipate the arrival of patients requiring immediate intervention. Intervention is based on the individual patient's injuries and must be coordinated through the entire health care environment. Assessment of each patient is critical at the point of triage and again at the patient's arrival in the emergency department (ED). Of particular importance is airway management and fluid resuscitation. Adherence to standard ABC (airway, breathing, circulation) resuscitation techniques reduces mortality in the short-term following a disaster.[5]

A secondary assessment helps to identify internal injuries to the patient and aids in planning ongoing care for the patient. At this time a history should be obtained that will, among other things, determine a patient's location relative to the explosion. The examiner should conduct a thorough exam of the thorax and abdomen to rule out occult injuries to the respiratory system or gastrointestinal tract.

Victims of explosions should be monitored for exposure to chemical or radioactive contaminants.[7,10,13,14] Monitoring should be initiated at the detonation site by trained emergency personnel and continued at the hospital using appropriate equipment. The hospital safety officer and radiation safety officer should be responsible for such monitoring and for implementing adequate decontamination processes.

Primary blast injuries

The properties of a detonation (air being compressed more readily than fluid) indicate that most primary injuries will be to hollow or gas-filled structures. Thus the ear, respiratory system and gastrointestinal tract are most prone to damage from an explosion.[1,2,10,12,13,14] The ear is the most sensitive of these systems.[3]

Ears

The tympanic membranes (TM) of all victims of an explosion should be evaluated for perforation or hemotympanum. In one report, 45% of fatalities from explosions suffered TM injuries.[12] The head, eyes, ears, nose and throat (HEENT) exam may identify a perforated TM.

The TM separates the external auditory canal from the structures of the middle and inner ear. Pressure of 5 pounds per square inch (psi) can rupture the tympanic membrane.[3,15] The auditory ossicles may also be fractured or dislocated during an explosion, although there is typically no damage to the inner ear.

These patients are managed medically, and routine surgical intervention is not required. Individuals with ossicular chain injury may be candidates for reconstruction at a later time. A significant proportion of victims suffering otologic injury experience permanent hearing deficit including complete loss of hearing.

Patients with injuries involving the TM should be evaluated for pulmonary injuries, as a significant number of these patients also suffer from pulmonary complications. Absence of TM injury does not rule out injury to the pulmonary system or gastrointestinal tract.[15]

Eyes

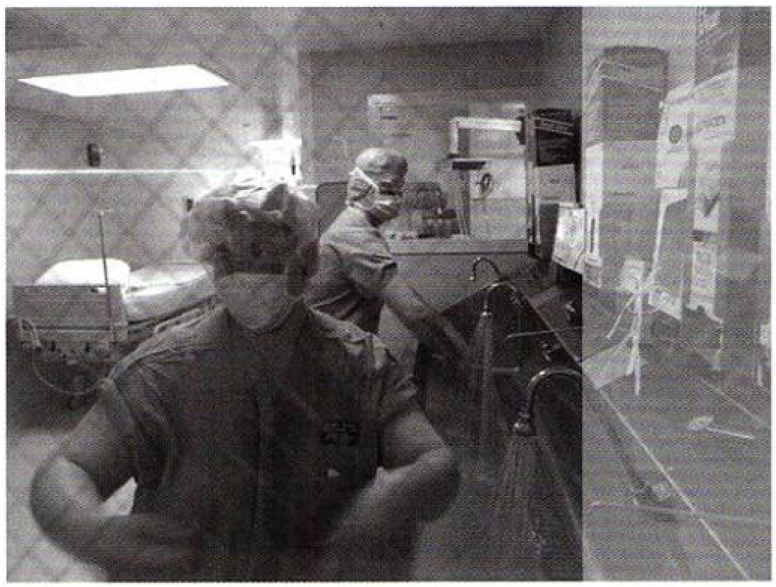
Ophthalmic injuries are typically related to secondary blast injury though many of these are superficial and include corneal abrasions and lacerations. These are frequently related to dust particles carried by the force of the explosion. The globe is not easily injured by explosive forces and most superficial injuries can be treated in the emergency department. The exception to this involves patients who have suffered penetrating injuries of the globe due to flying debris. These patients may require surgical intervention after critically injured patients have been stabilized.[1]

Respiratory system

Primary blast injuries or complications involving the respiratory system include pulmonary contusion, pulmonary edema secondary to myocardial contusion and pneumothorax. Victims of explosions are at significant risk for development of Adult Respiratory Distress Syndrome (ARDS) and should be monitored for this complication. ARDS may result from the inhalation of gases or dust associated with the explosion or as a result of barotrauma to the lung tissue itself.[10]

Any patient presenting with wheezing should be evaluated to rule out pulmonary contusion, as this is the most common, and potentially fatal, respiratory complication associated with primary blast injury. Patients with respiratory insult are not candidates for surgical intervention as they are treated with anti-inflammatory agents and oxygen therapy.

Chest tubes may be inserted in the emergency department as required to alleviate pneumothorax or hemothorax. Surgical staff members should be prepared for intraoperative placement of chest tubes on patients who develop symp-



toms of pneumothorax or tension pneumothorax while in surgery.

Neurological system

A common and frequently fatal complication of blast injury is the development of arterial gas embolism (AGE). This condition often affects the smaller vessels of the brain, coronary arteries and spinal cord. Symptoms of central nervous system (CNS) injury must be differentiated from AGE to provide proper treatment. Patients with AGE may require hyperbaric therapy as part of stabilization. Surgical patients should be positioned in the left lateral recumbent position when possible to prevent air emboli from migrating up the carotid vessels. Trendelenburg position is no longer recommended for these patients due to concerns about intracranial pressure (ICP) elevation.[10,12] As AGE may present several hours after the explosion, patients undergoing surgical intervention may require monitoring for development of this complication. Evaluation may include cerebral angiography, nerve impulse monitoring and vertebral or cord angiography.

Gastrointestinal system

Gastrointestinal injuries are commonly noted with underwater explosions but are frequently noted with enclosed space explosions. Injuries

associated with the gastrointestinal tract involve contusions of the lower intestinal tract, hematoma formation within the muscularis layer of the small intestine and omentum, and shearing of the ligaments supporting the structures of the peritoneal cavity.[2,14,15,17,18,19] Injury to intraabdominal structures often occurs as a result of compression or deceleration forces (primary or tertiary injury).[12,18,19]

Compression injuries result from blunt trauma to the abdominal wall as seen in patients suffering primary or tertiary blast injury. This force deforms abdominal viscous and, consequently, increases intraluminal pressure of the GI tract which may lead to rupture or tearing of these structures, particularly the colon. These injuries can lead to necrosis of portions of the GI tract or gross contamination of the peritoneal cavity. Compression of the solid organs (eg, liver, spleen) can lead to the formation of intracapsular hematomas and is commonly associated with tertiary blast injury.[19,20,21]

Patients presenting with increasing abdominal pain, nausea and vomiting should be evaluated using ultrasound and CT. Abdominal organ injuries often present a number of hours after the explosion and may not be identified during initial examination.[23,24,25] These often require surgical interventions that include bowel resections, repair of serosa and intestinal reanastomosis or colostomy.[26]

Secondary blast injuries

Secondary blast injuries result in the high morbidity and mortality among victims, as these are associated with massive hemorrhage, foreign body implantation and the likely involvement of multiple structures of the body. Of particular importance to health care workers is the fact that civilian terrorists frequently use screws, nails and other metal pieces as components of explosive devices to cause significant injury to their victims.[14,28,29] Military munitions, such as hand grenades and cluster bombs, are designed to fragment and have similar results.[1,2]

Solid organ injury is not typically associated with primary blast injury. These structures are more frequently injured as a result of secondary, tertiary or miscellaneous blast mechanisms. Most commonly, the liver is affected followed by the spleen and the kidneys. Routine urinalysis is indicated for all victims of blast injury and gross hematuria requires a cystogram.[27] Progressive abdominal pain and changes in hemodynamic status indicate injuries involving the liver and/or spleen and appropriate diagnostic tests should be performed.[24,25] Depending on patient volume and hospital resources, a diagnostic peritoneal lavage (DPL) may be the quickest method of determining injury to solid or vascular structures of the abdomen.[23] Hemoperitoneum in the presence of unstable vital signs requires immediate surgical intervention. Surgical staff members should be prepared for injuries to the liver and hepatic arteries, portal vein, spleen, abdominal aorta and injuries to the renal vessels.[16,17,18,22] Injury to any of these structures constitutes a true surgical emergency and staff members should be prepared accordingly.

Secondary blast injury involving penetration of the abdominal wall requires surgical exploration to rule out perforation of viscous, laceration to the liver, kidneys, spleen or major vessels and injury to the serosa and omentum. These patients, if stable, may be deferred until critical patients are stabilized. Patients who are deferred must be monitored for adverse changes in status. The surgical team should be prepared to perform repairs to the hollow viscous and to address injuries to the liver, spleen or major vessels.

Penetration of the thorax subsequent to secondary blast injury results in pneumothorax or hemothorax. These patients are typically managed by placement of chest tubes and monitoring for hemodynamic instability. Penetrating objects that traverse the mediastinum require emergency thoracotomy or emergency mediastinal exploration.[14,22]

The head, face and neck are quite prone to secondary blast injury and multiple lacerations and puncture wounds may be noted. With the exception of injuries involving the trachea, carotid arteries and jugular veins, most of these patients can be cared for in the emergency department or triage area, stabilized and deferred until critical patients are cared for.

Secondary blast injuries involving the extremities include lacerations, avulsions, puncture wounds and traumatic amputations. Amputations are the most severe of these injuries and require immediate control of hemorrhage and prompt surgical intervention. In most cases, limb salvage following traumatic amputation is not possible based on the resources available and patient volume. Surgical intervention for extremity injuries involves tissue debridement and hemostasis. These wounds are closed by second or third intention and may require skin-grafting or extensive reconstruction. These

A few physics facts

We are surrounded by the presence of many types of waves: sound waves, microwaves, light waves, shock waves, water waves and stadium waves are just a few examples. It is the phenomena of waves that underlie much of the damage that can be suffered by victims in terrorist attacks. A dictionary of terms related to waves and some of the phenomena discussed in the article is available here for your reference.

Amplitude—The maximum amount of displacement of a particle from its rest position through the medium.

Boundary—The juncture where one medium ends and another medium begins.

Boundary Behavior—When a wave reaches the end of a medium and reacts to the beginning of another medium, the consequent result is termed boundary behavior. For example, when a sound wave moves through air and reaches a rock wall, it returns to its original source, producing an echo.

Combustion—A chemical reaction that produces heat and light.

Displacement—When an object moves position and travels in a direction from its original location, the process is called displacement.

Energy Transport Phenomenon—When a disturbance travels through some type of medium, particle-to-particle, energy is being transported from the starting point of the disturbance to another location. This process characterizes waves as an energy transport phenomenon.

Equilibrium—The position of the medium before the disturbance commences is called equilibrium or the rest position.

Exothermic—A chemical or physical event that causes heat to be released is defined as exothermic (heat-producing).

Force—The push or pull exerted by or exerted on an object.

Pulse—A single disturbance moving through a medium from one location to another location.

Pressure—The numeric value derived when an object of a specific weight (force) comes into contact with an area of a specific size.

Speed—The distance traveled by a given point on the wave in a specific period of time.

Wave—A wave is a disturbance that moves through a medium from one location to another location. It results when a vibrating source displaces the first particle of the medium to initiate the disturbance.

Wave cycle—Each wave causes a repeating pattern of disturbance. One repetition is called a wave cycle.

Wavelength—The length of one particular repetition.

injuries are also associated with fractures, and external fixation may be the most appropriate means of fracture stabilization during a mass-casualty crisis.

Tertiary blast injuries

Tertiary injuries result from the body being lifted by the blast forces and propelled into another body or solid object. The specific injuries associated with this force include musculoskeletal injuries, deceleration injuries and neurological injuries. Musculoskeletal injuries include fractures and dislocations.

The vertebrae are prone to compression fractures and the subluxation of one or more levels of the vertebral column is not an uncommon tertiary injury. Compression fracture of a vertebra occurs when the body is stopped by a solid object (eg wall, cabinet) and the deceleration and compression forces are directed through the vertebral bodies.[30,31] This injury may also be associated with intervertebral disc herniation particularly if the direction of force is down the longitudinal axis of the vertebral column.

Subluxation (or dislocation) of a vertebra can occur when the anterior-posterior movement of one vertebra is halted but the vertebrae above or below continue in the direction of travel. The cervical vertebrae, due to their relatively small size and weak supporting structures, are especially prone to subluxation injuries. Subluxation of the vertebrae can cause compression or transection of the spinal cord. Injuries involving the C-1 to C-2 vertebra can lead to compression or transection of the proximal spinal cord and are frequently fatal. Injury to the spinal cord above the level of C-4 can result in paralysis of the diaphragm and subsequent loss of spontaneous respiration.

Edema associated with spinal cord injury may cause hypoperfusion and anoxia. Patients with suspected spinal cord injury must be immobilized, evaluated and treated promptly to prevent irreversible neurological insult.[30] Traction is appropriate in an otherwise stable patient. However, patients diagnosed with unstable cervical spine fractures ultimately require surgical intervention as cord edema recedes.

Most fractures involve the long bones, although fractures of the carpals and interphalangeal (IP) dislocations are noted. Tertiary blast injuries result in transverse and spiral fractures of the legs and arms, and these may be open or closed fractures. Depending on patient volume, these may be reduced and stabilized using traction, splinting or external fixator application. Open wounds must be debrided within four hours in a surgical setting and external fixation or intramedullary (IM) nailing techniques used to stabilize these fractures. The surgical team must coordinate with the radiology department to ensure adequate care for these patients. These patients may also suffer vascular compromise to the distal extremity and may require femoropopliteal bypass or a similar technique.

Other fractures of note include cranial and rib fractures. A depressed skull fracture is identified when a free fragment of a skull fracture is pushed beneath the level of the intact cranium. This type of fracture is considered a surgical emergency and an emergency craniotomy or cranioplasty is needed. Rib fractures do not routinely constitute a medical or surgical emergency unless the patient is suffering from, "flail chest." Flail chest occurs when one or more ribs become fractured in two places along the length of the rib.[32] This causes the rib(s) to deviate inward with inspiration and results in diminished respiratory capacity. Flail chest may indicate more serious injury to structures within the thoracic cavity.

Forces of deceleration result in the stretching and shearing of supportive abdominal structures (eg, falciform ligament, suspensory ligaments). These forces also lend themselves to causing intimal injuries to vascular structures, namely the renal or hepatic arteries. Note that deceleration forces are implicated in thoracic aorta transection and shearing of the ligamentum arteriosum. Evaluation of hemodynamically unstable patients suffering deceleration injury should include ruling out aortic transection using ultrasound or A/P chest radiography (CXR, aortogram).[5,22]

Miscellaneous blast injuries involve burns, smoke inhalation and crush injuries that result from structural collapse or falling debris. Burn injuries must be promptly debrided to prevent further thermal insult and to remove necrotic tissue that fosters the growth of microorganisms. Skin grafting may be performed at this time depending on institutional practices, patient load and individual patient's stability. Victims of crush injuries must be monitored for the development of compartment syndromes. These patients may require fasciotomies of one or more extremities or the abdomen. Crush injuries result in a significant number of fractures that require surgical intervention. Patients must be monitored for tissue perfusion and for myoglobinuria, a common indicator of necrosis of muscular tissue.[14,18]

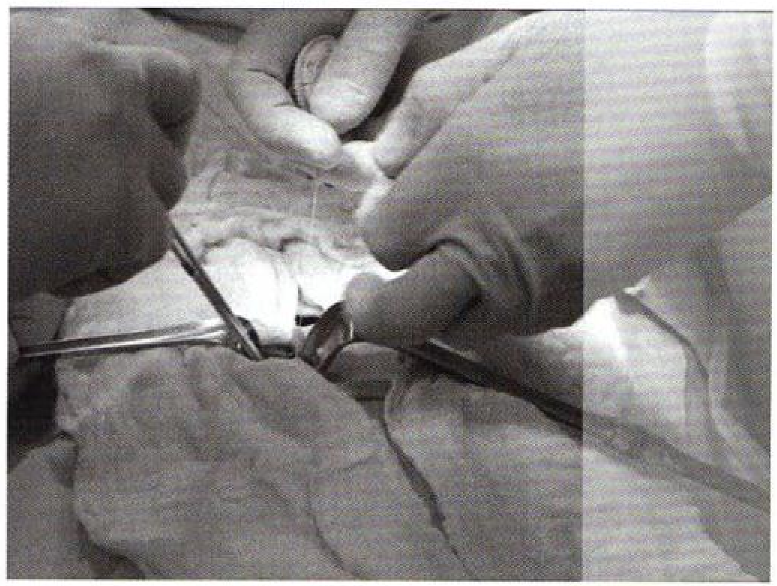
Explosions and the pregnant patient

Because fluid is not easily compressed, the fetus within the placenta should remain uninjured as a result of primary blast forces. However, due to varying tissue densities, the placenta itself is prone to tearing from the uterine wall. As a result, significant hemorrhage and leakage of placental fluid may occur. All victims of an explosion who are within the second or third trimester of pregnancy should undergo ultrasound examination and evaluation for fetal distress.[33,34] Secondary and miscellaneous blast injuries may result in significant morbidity to the fetus, particularly if the integrity of the placenta is interrupted. An obstetrician should be available to evaluate the pregnant patient and surgical staff members should anticipate the need for emergency cesarean section and/or hysterectomy on the pregnant patient.

Accurate determination of fetal age is vital to ensure adequate treatment and resource allotment. Gestational age of less than 23 weeks indicates a nonviable fetus, and all resuscitation efforts should focus on the mother. A fetus of greater than 23 weeks gestation may be viable, and appropriate treatment should be rendered to both mother and fetus.[34]

Prior to the 23rd week of gestation, the fetus is protected by the bony pelvis. As development continues, the uterus enlarges and begins to occupy part of the abdominal cavity as well. The urinary bladder is also displaced superiorly and anteriorly. These structures subsequently become more prone to blast injury as the pregnancy progresses.

Placental abruption and uterine perforation or rupture are the two most serious surgical concerns related to the patient. These are associated with high morbidity and mortality of both mother and fetus and require immediate surgical intervention to assure the viability of either. Surgical staff members should be prepared to perform a perimortem Cesarean section. This decision should be based on the viability of the fetus (>23 weeks) and the duration of cardiopulmonary

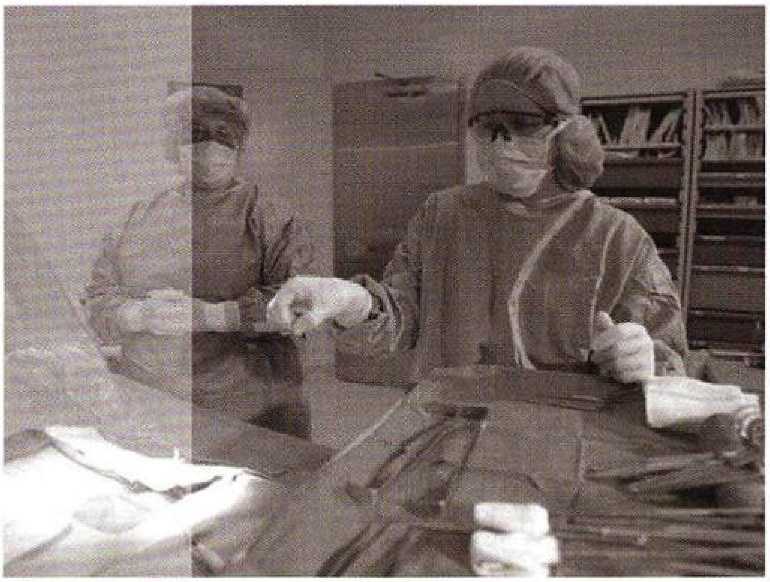


resuscitation on the maternal patient.[34] This procedure must commence within four minutes of initiating CPR. It should be noted that maternal resuscitation has occurred following emergency C-section on the perimortem patient.[34]

Laboratory testing

All victims of an explosion should undergo specific baseline lab testing, including complete blood count (CBC) and urinalysis (UA). Patients should be typed and screened (T&S) or typed and crossmatched (T&C) depending on the patient's initial presentation to the emergency department. Patients who were exposed to a fire or an enclosed space detonation should be evaluated for carbon monoxide (CO) levels. Carbon monoxide binds more readily to hemoglobin than oxygen and patients with elevated carboxyhemoglobin (COHb) levels should be treated with 100% oxygen (O_2) via a tight-fitting mask to ensure adequate oxygenation. Ventilatory support may be required for these patients.

Chest and abdominal radiography may be helpful, although often not on initial admission. Many intrathoracic and intraabdominal injuries present several hours after an explosion, therefore X-ray and computed tomography (CT) should be considered for any patient complaining of increasing abdominal pain or of impaired respiratory function.[5,10,14]



Conclusion

The threat of terrorist actions on our nation should cause each of us to evaluate our responsibilities during a mass casualty crisis. Accidental explosions present themselves in a similar fashion, however there are significant differences. Intentional explosions are designed to injure or kill en masse, frequently without warning. Manufactured explosive devices often include metal shrapnel to maximize the number of casualties, types of injury and physical damage to the area. Intentional detonations may be designed to contaminate the vicinity with biological, chemical or radiological particles. Monitoring for this should commence any time there is a suspected intentional explosion.

Surgical team members must be prepared to address the various needs of victims of intentional blast injury. Although the surgical team cannot know specific injuries, they can anticipate certain surgical interventions. In the immediate aftermath of an explosion, the surgical team should be prepared to perform procedures to address secondary and miscellaneous blast injuries, including tissue debridement and external fixation. Less commonly, laparotomies are performed on patients who are hemodynamically unstable or who have penetrating wounds of the abdomen.

Four to 24 hours after the initial explosion, the surgical team should prepare for patients who have suffered primary blast injuries that, due to the nature of these injuries, have not been identified during the primary and secondary assessments. This group of patients will frequently require exploratory laparotomy, craniotomy and, possibly, thoracotomy. Twelve to 96 hours following an explosion, patients will return for secondary tissue debridement, dressing changes and fasciotomies.

Surgical personnel can learn whether an explosion was an enclosed space explosion or an open-air detonation to help them aid in patient-care preparations. Patients who have been exposed to an enclosed space detonation will have more severe injuries and a greater likelihood of occult injuries. These patients will require early medical stabilization and, as their conditions deteriorate, identification of hidden injuries. Victims of an enclosed space explosion are likely to suffer tertiary blast injuries that may include fractures, dislocations and traumatic amputations.

Thorough observation is required in an intensive care unit (ICU) setting or other monitored area for at least four hours postadmission for patients with no outward injuries. Due to the high incidence of occult injury in this patient group, these individuals must be instructed to return to the hospital with any increase in abdominal pain or respiratory embarrassment.

Enclosed space and underwater detonations have a much higher morbidity and mortality than open-air explosions.

Victims of open-air explosions are likely to endure significant secondary blast injuries, including penetrating wounds and traumatic amputations due to flying debris. Patients admitted to the hospital following an open-air explosion will frequently require surgical intervention such as wound exploration and tissue debridement, application of external fixation devices or IM nailing, exploratory laparotomies and thoracotomies. This victim is less likely to suffer occult injuries, and the surgical staff should anticipate a patient load requiring secondary tissue debridement and skin grafting procedures after the first 24 hours.

The impact of surgical services personnel on the morbidity and mortality of explosion victims can be significant. Anticipating injuries based on the type of detonation can eliminate waiting for appropriate instruments and supplies and can allow staff members to respond to such a crisis effectively and economically. Anticipating the needs of the surgeon and the patient will allow surgical team members to focus on the patient's injuries and will enhance the care of the surgical patient at their time of greatest need.

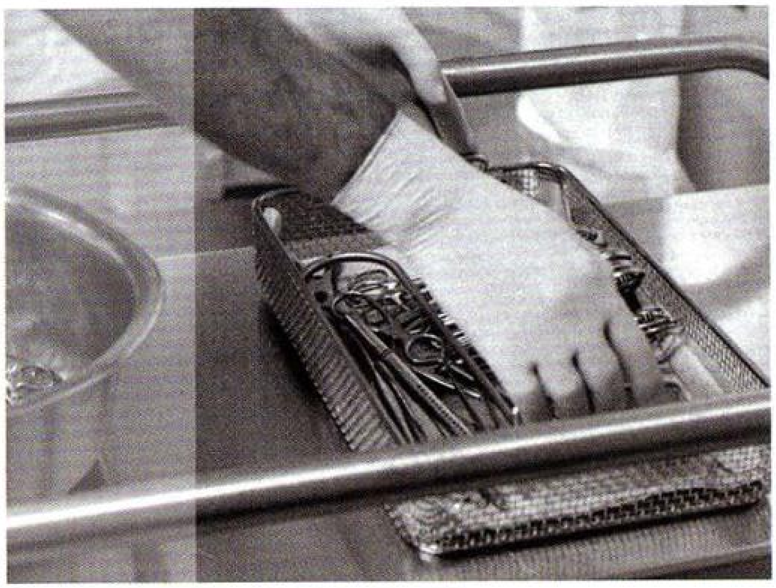
About the author

Ken Warnock, CST, has 17 years of experience working as a surgical technologist and surgical assistant. He is currently employed by William Beaumont Hospital and is the program instructor for the Oakland Community College and William Beaumont Hospital Surgical Technology Program. He has served on the Trauma Task Force at Beaumont and works with the trauma service.

References

1. Bowen TE, Bellamy RF. *Emergency War Surgery.* US Government Printing Office; 1988.
2. Cernak I, Savic J, et al. Blast injury from explosive munitions. *J Trauma;* July 1999; 47(1): 96-103.
3. Garth RJ. Blast injury of the ear: an overview and guide to management. *Injury.* July 1995; 26(6): 363-6.
4. Beckstead M. *Fundamentals of Combustion and Detonation.* University of Utah Center for the Simulation of Accidental Fires and Explosions (C-SAFE). **www.csafe.utah.edu** Accessed 12/01
5. Sheehy SB, Blansfield JS, et al. *Manual of Critical Trauma Care,* 3rd ed. St Louis: Mosby; 1999.
6. Staten CL. Emergency response to chemical/biological terrorist incidents. Emergency Response and Research Institute (ERRI). **www.emergency.com** Accessed 12/01
7. Smith-Akin CK. Biological and chemical terrorism: strategic plan for preparedness and response. *MMWR.* April 2000; 49(RR-4): 2-14.
8. Tucker JB. Historical trends related to bioterrorism: an empirical analysis. *Emerg Inf Dis.* **www.cdc.gov/ncidod/eid/vol5no4/tucker.htm** Accessed 12/01
9. Torok TJ, Tauxe, RV, et al. A large community outbreak of salmonellosis caused by intentional contamination of restaurant salad bars. *JAMA.* August 1997; 278(5): 389-95.
10. Lavonas E. Blast injuries. **www.emedicine.com/emerg/topic63.htm** Accessed 12/01
11. Leibovici D, Gofrit ON, et al. Blast injuries: bus versus open-air bombings—a comparative study of open-air versus confined-space explosions. *J Trauma.* December 1996; 41(6): 1030-5.
12. Mayorga MA. The pathology of primary blast overpressure injury. *Toxicology.* July 1997; 121(1): 17-28.
13. Argyros GJ. Management of primary blast injury. *Toxicology.* July 25, 1997; 121(1): 105-15.
14. Guzzi LM, Argyros G. The management of blast injury. *Eur J Emer Med.* December 1996; 3(4): 252-5.
15. Leibovici D, Gofrit ON, Shapira SC. Eardrum perforation in explosion survivors: is it a marker of pulmonary blast injury? *Ann Emerg Med.* August 1999; 34(2): 168-72.

16. Carico CJ, Thal ER, Weigelt JA. *Operative Trauma Management: An Atlas.* Stamford, Conn: Appleton & Lange; 1998.
17. Ivatury RY, Cayten CG. *Textbook of Penetrating Trauma, The.* Philadelphia, Pa: Williams & Wilkins; 1996.
18. McMurtry RY, McClellan BA. *Management of Blunt Trauma.* Philadelphia, Pa: Williams & Wilkins; 1990.
19. Salomone JA III. Abdominal trauma, blunt. ***www.emedicine.com/EMERG/topic1.htm*** Accessed 12/01
20. Akhrass R, Yaffe MB, Brandt CP. Pancreatic trauma: a ten-year multi-institutional experience. *Am Surg.* July 1997; 63(7): 598-604.



21. Smith JS Jr, Wengrovitz MA, DeLong BS. Prospective validation of criteria, including age, for safe, nonsurgical management of the ruptured spleen. *J Trauma.* September 1992; 33(3): 363-8.
22. Donovan AJ. *Trauma Surgery: Techniques in Thoracic, Abdominal and Vascular Surgery.* St Louis, Mo: Mosby; 1994.
23. Bellows CF, Salomone JP, Nakamura SK. What's black and white and red (read) all over? The bedside interpretation of diagnostic peritoneal lavage fluid. *Am Surg.* February 1998; 64(2): 112-8.
24. Branney SW, Moore EE. Cantrill SV. Ultrasound based key clinical pathway reduces the use of hospital resources for the evaluation of blunt abdominal trauma. *J Trauma.* June 1997; 42(6): 1086-90.
25. Chiu WC, Cushing BM, et al. Abdominal injuries without hemoperitoneum: a potential limitation of focused abdominal sonography for trauma (FAST). *J Trauma.* April 1997; 42(4): 617-23.
26. Talton DS, Craig MH, et al. Major gastroenteric injuries from blunt trauma. *Am Surg.* January 1995; 61(1): 69-73.
27. Knudson, MM, McAnnich JW, et al. Hematuria as a predictor of abdominal injury after blunt trauma. *Am J Surg.* November 1992; 164(5): 482-5.
28. Hiss J, Kahana T. Suicide bombers in Israel. *Am J Forensic Med Pathol.* March 1998; 19(1): 63-6.
29. Katz E, Ofek B, et al. Primary blast injury after a bomb explosion in a civilian bus. *Ann Surg.* April 1989; 209(4): 484-8.
30. Daffner RH. *Imaging of Vertebral Trauma.* Gaithersburg, Md: Aspen; 1988.
31. Jeffreys E, ed. *Disorders of the Cervical Spine,* 2nd ed. Boston, Mass: Butterworth-Heinemann; 1993.
32. Branney SW, Moore EE, Feldhaus KM. Critical analysis of two decades of experience with post-injury emergency department thoracotomy in a regional trauma center. *J Trauma.* July 1998; 45(1): 87-94.
33. Dahmus MA, Sibai BM. Blunt abdominal trauma: are there any predictive factors for abruptio placentae or maternal-fetal distress? *Am J Obstet Gynecol.* October 1993; 169(4): 1054-9.
34. Swendner K. *Trauma in Pregnancy: clinical management in the perioperative areas; Presented at: Care of the Pregnant Trauma Patient [conference];* Royal Oak, MI. October 2001.

CE Exam

CONTINUING EDUCATION EXAMINATION

Terrorism and its impact on the practice of surgery

Earn CE credit at home

You will be awarded one continuing education (CE) credit for recertification after reading the designated article and completing the exam with a score of 70% or better.

If you are a current AST member and are certified, credit earned through completion of the CE exam will automatically be recorded in your file—you do not have to submit a CE reporting form. A printout of all the CE credits you have earned, including Journal CE credits, will be mailed to you in the first quarter following the end of the calendar year. You may check the status of your CE record with AST at any time.

If you are not an AST member or not certified, you will be notified by mail when *Journal* credits are submitted, but your credits will not be recorded in AST's files.

Detach or photocopy the answer block, include your check or money order made payable to AST and send it to the Accounting Department, AST, 6 West Dry Creek Circle, Suite 200, Littleton, CO 80120-8031.

Members: $6 per CE, nonmembers: $10 per CE

1. Choking agents, nerve agents and blister agents are all classes of ____.

a. nuclear weapons
b. biological weapons
c. chemical weapons
d. incendiary weapons

2. Which is likely to have the greatest impact on the operating room setting?

a. biological weapons
b. chemical weapons
c. incendiary weapons
d. none of the above

3. Which class of blast injury is caused by the propulsion of the shock wave?

a. primary
b. secondary
c. tertiary
d. miscellaneous

4. Which class of blast injury is caused by the shock wave's direct impact on the body?

a. primary
b. secondary
c. tertiary
d. miscellaneous

5. Which class of blast injury is often associated with massive hemorrhage and foreign body implantation?

a. primary
b. secondary
c. tertiary
d. all of the above

6. The shock wave that follows an explosion causes damage because of its ____.

a. force
b. pressure
c. thermodynamic energy
d. all of the above

7. Which is not usually at risk of primary blast injury?

a. ear
b. liver
c. respiratory system
d. intestine

8. Which condition may present several hours after the blast?

a. arterial gas embolism
b. adult respiratory distress syndrome
c. abdominal organ injuries
d. all of the above

9. Vertebral subluxation and compression fractures are from which class of blast injury?

a. primary
b. secondary
c. tertiary
d. miscellaneous

10. When a hospital learns of an enclosed space explosion, what should they expect?

a. primary blast injuries
b. tertiary blast injuries
c. occult injuries
d. all of the above

---

214 MAY 2002 CATEGORY 1

Terrorism and its impact on the practice of surgery

☐ Certified Member ☐ Certified Nonmember

Certification No ______________________

Name ______________________

Address ______________________

City ______________ State ______ ZIP ________

Telephone ______________________

	a	b	c	d		a	b	c	d
1	☐	☐	☐	☐	6	☐	☐	☐	☐
2	☐	☐	☐	☐	7	☐	☐	☐	☐
3	☐	☐	☐	☐	8	☐	☐	☐	☐
4	☐	☐	☐	☐	9	☐	☐	☐	☐
5	☐	☐	☐	☐	10	☐	☐	☐	☐

Mark one box next to each number. Only one correct or best answer can be selected for each question.