

Immediate Bystander Aid in Blast and Ballistic Trauma

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In today's world, anyone could be a first responder by being present at a terrorist event or other natural or social disaster that has a medical environment similar to that on the battlefield.

From experience gained in combat, we have learned many ways to reduce mortality. Military researchers have found that approximately 25 percent of persons who die as a result of explosives or gunshot wounds have potentially survivable wounds if appropriate care can be initiated close to the time of injury.¹

In earlier wars, the ratio of wounded to dead was 3:1. It is now approximately 40:1. This is partly because of body armor and partly because of training every soldier, at least in special operations, in the doctrine of Tactical Combat Casualty Care or TCCC. TCCC is designed by the military to address the management of survivable wounds and it is taught to all SEALs, Army Rangers, and Special Forces, as well as all Army medics and Navy corpsmen. The purpose is to reduce a death from the preventable causes resulting from blast and ballistic injury until higher-level care can be provided. In order to translate these military lessons into guidelines appropriate for the civilian population and environment, the Committee for Tactical Emergency Casualty Care (C-TECC) was convened.^{2,3}

Lessons from the Boston Marathon

On April 15, 2013, two explosions occurred 12 seconds apart at the Boston Marathon finish line. There were no other tertiary explosive devices. Casualties included three dead and 264 wounded.

Several lessons learned by the U.S. military were reinforced during the civilian emergency response to the bombing. In addition, Boston has seven trauma centers and many world-class hospitals. A large number of police, security, and emergency medical services (EMS) personnel were already deployed at the scene. The bombers detonated relatively low-yield devices outdoors, and absence of structural collapse facilitated rapid evacuation of victims. In addition, the bombing occurred outdoors next to a wide street rather than in an enclosed space, or with walls that could concentrate blast waves.⁴ It must also be mentioned that Boston has frequent emergency drills, and EMS has incorporated lessons from TCCC such as the use of tourniquets and associated training in its hemorrhage-control protocol.⁵ However, to be effective, tourniquets need to be brought to the site of an incident. Many of the improvised tourniquets failed and had to be replaced.

The police were the first on the scene but had no training in controlling hemorrhage and no lightweight tourniquets or pressure bandages. A first-hand account by a physician who was at the scene illustrates how ill-prepared many physicians

are to cope with such an event. One said, "I took off my belt and went to put it around someone's leg, but then I saw they already had a tourniquet." And he "watched these passing victims in a kind of idle horror, with no idea how to help." A family physician with no knowledge of how to care for horrific trauma could do nothing except sit beside patients with minor injuries who were dazed and in psychological shock.⁶

A nearby medical tent had already been set up to handle medical emergencies including dehydration and minor trauma, and this was quickly reconfigured as a casualty collection point where the bombing victims were stabilized and evacuated quickly to area hospitals. The scene remained essentially unsafe throughout the response, owing to the risk of additional explosive devices. Terrorists often deliberately employ these just at the time that first responders begin to arrive so that the responders become victims as well.

The ability to control catastrophic hemorrhage and provide an airway should be a basic skill of every police officer on the street, but at this time in many places it is not part of their basic training.

Priorities

In an event with mass casualties, the treatment priorities are very different from those in more common medical emergencies. In the latter, the priorities are ABC: airway, breathing, circulation. In a mass casualty event, the focus is on the preventable conditions that can rapidly cause death.

First, a casualty's catastrophic hemorrhage if it is present must be controlled. Then, the airway is managed. Unconscious patients should be put in the recovery position described below. This is followed by a careful examination of the chest and the sealing of open chest wounds with an occlusive dressing. Then it is necessary to identify casualties that require immediate advanced care. Cardiopulmonary resuscitation (CPR) is not done in such blast and ballistic injury situations. A number of repeatable studies have shown that CPR for cardiopulmonary arrest due to trauma is not effective. It is useful only in certain situations such as drowning, hypothermia, electrocution, and cardiovascular incidents.

Hemorrhage control is always the first priority as a person can exsanguinate within 90 seconds to three minutes from a severed femoral artery and vein, whereas a patient can survive several minutes with an obstructed airway.

Mechanism of Blast Injury

An explosion converts a solid or liquid into highly pressurized gases that compress the surrounding air. There is

a thermal pulse, a pressure wave or blast wind, and shrapnel. The thermal pulse causes burns that can be severe. The over-pressure wave can cause fractures or partial or complete traumatic amputations. Debris, bone fragments, and other tissues can be driven up between proximal tissue planes, and muscles can be stripped from the bone. The fragments and debris can be traveling at up to 1,000 to 5,900 feet per second.

Rupture of the tympanic membrane is common from exposure to an over-pressure wave. It may be an isolated injury, or can be associated with other blast injuries. Its presence does not necessarily indicate that more sinister blast injuries exist. However, there will be immediate hearing loss, and this must be taken into account when treating a conscious patient. Fortunately, most of these spontaneous perforations usually resolve without surgery.

The pressure wave can also travel down the trachea, causing alveolar rupture. Air embolism, from direct leak of air from the alveolar and bronchial tree into the pulmonary vasculature, is the most common cause of death from blast, and this normally occurs within hours. It may produce cutis marmorata, chest pain, stroke, tongue blanching, and unilateral blindness. The blast wave may also cause contusions of the bowel wall leading to perforation 24 hours to even a week later.

The blast causes damage to brain by cavitation effects and torsional strain on connecting nerve fibers in the white matter that become stretched and broken. This axonal injury may be severe. Unconsciousness is the hallmark sign of non-penetrating blast-induced traumatic brain injury, and the length of time of unconsciousness is directly proportional to the severity of brain injury. Symptoms indicative of mild TBI after recovery include headache, fatigue, and later persisting poor concentration, lethargy, amnesia, or other constitutional symptoms. On previous battlefields a century ago this was termed "shell shock."

It must be remembered that in blast victims, even a small penetrating skin wound may be accompanied by devastating underlying trauma.

Up to 10 percent of blast-induced injuries may be accompanied by a significant penetrating eye injury with initially only mild discomfort. Symptoms include pain; photophobia; a sense of burning, irritation, or foreign body; altered vision; and periorbital swelling. Penetrating injuries to the eye are treated with utmost urgency in an attempt to prevent infection and later enucleation and avoidance of sympathetic ophthalmia. Anyone with an eye injury due to blast deserves the same priority as someone with an amputation and catastrophic hemorrhage if circumstances permit.

Control of Hemorrhage

The adult male has about 5 liters of blood. Rapid loss of 2,000 cc will result in severe shock and the loss of an additional 500 cc will likely lead to death of the individual if not immediately corrected. A useful guideline is that only 500 cc of blood separate life from death in a trauma casualty. Those casualties that have been in a state of prolonged stagnated capillary blood flow or "shock" are prone to the development of multiple organ

dysfunction and failure, and death several days to weeks later owing to progressive organ failure with shock kidney, shock lung, and shock liver. In shock, aerobic metabolism is converted to anaerobic with lactic acid production, and not enough energy is produced to maintain core body temperature. Note that clotting occurs only within a certain range of temperature and pH.

Therefore the first step in TECC is to control accessible hemorrhage. For an extremity, immediate direct pressure should be applied to a pressure point on the patient. Figure 1 shows direct pressure applied by the simple placement of the rescuer's knee. Alternately, the rescuer can place his lower leg across the casualty's femoral artery to exert direct pressure.



Figure 1. Immediate Pressure Point Technique

If the entire limb is not exposed, apply the tourniquet over clothing as proximally as possible. If the injury is exposed and the entire limb visible, the tourniquet can be placed 2 to 3 inches above the highest identified injury. If you do not have a tourniquet, look for materials to make expedient one; waist belts do not work. Figure 2 shows an expedient tourniquet. A 3-foot by 3-inch strip of clothing can be used. Four pencils or pens strapped together can serve as a windlass. The windlass must be pulled outward as twists are applied to get the tourniquet effectively tight.



Figure 2. A Cravat-and-Windlass Tourniquet

Amputations, partial or complete, even if not visibly bleeding at the time, eventually will require a tourniquet. The tourniquet should be applied as soon as the situation will allow, and prior to the onset of shock, to decrease mortality. If bleeding is not controlled with the first tourniquet, a second one is applied proximal to the first. The time the tourniquet is applied should be noted. Keep in mind that studies have shown that permanent damage to an arm or leg is rare if the tourniquet is left on less than 111 minutes. Pneumatic tourniquets are often left in place for more than two hours during elective surgical procedures. Rescuers should not perform “perfusion intervals,” periodically releasing the tourniquet. This practice has proven to be detrimental. For decades, rescuers have been taught that a tourniquet is an

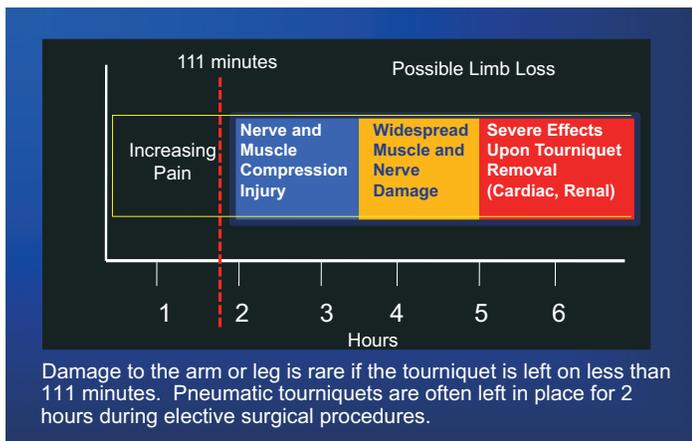


Figure 3. Tissue Damage after Tourniquet Application

absolute last resort. Fortunately, that view is changing.⁷

If the bleeding site is not anatomically amenable to a tourniquet, use a direct-pressure dressing. Any “foreign material” placed into a wound directly activates the clotting mechanism; and one wants clotting factors in the wound, not on the ground!

Fully expose the wound and pack tightly from wall to wall and apex to apex as deep into the wound as possible. Push it in “single file” as quickly as possible. A violent motion is needed to assure that every cranny is packed. The victim may not feel this, though it will be painful later.

The best material is crinkle-cut 4-ply gauze if available. Otherwise any gauze, cotton clothing, or any flexible material including a paper towel will work.

The packing needs to be secured with a wad of material over the opening and a pressure dressing. While wrapping an Ace or elastic wrap or other dressing around the limb, trauma may be minimized by securing the limb between your legs and leaning backward to elevate it slightly and apply traction. (Recall that any type of gunshot wound is likely associated with a fracture.) Then the limb does not have to be elevated repeatedly to get the dressing underneath. Be sure to put a half-hitch in at some point so that the whole dressing cannot unwind. Secure the end twice, recalling that “one is none and two is one.” The dressing needs to cover all

of the gauze packing so that it cannot be pulled out.

Four generations of hemostatic agents have been developed for wound packing. These incorporate proteins or chemicals designed to initiate and accelerate the fibrin clotting process. Some act chemically to seal damaged arteries and veins. Some are powders that can be poured into the wound, but all must be used with sustained direct pressure for at least three minutes. The current trend is to use a hemostatic agent that is incorporated in the packing material. The newer generation hemostatic agents do not have the side effects of previous versions.

Airway Management

If the victim is talking, he has a good airway. Airway obstruction can usually be diagnosed from afar by noting an abnormal respiratory effort, cyanosis, muscle retractions (intercostal, suprasternal, or subcostal), stridor or hoarseness, agitation, or decreasing consciousness. The obstruction may be caused by unconsciousness and loss of motor tone with the tongue blocking the airway; facial fractures; blood, vomitus, or other foreign material in the airway; increased pressure on the airway structures as from a neck hematoma; or airway wall edema from burns or smoke inhalation.

The airway may be opened with positioning, i.e. chin lift or jaw thrust technique. The military uses a nasopharyngeal airway in all unconscious casualties. When feasible, unconscious casualties should also be placed in the recovery position (Figure 4). In this position, the injured side of the chest is down, the head is turned to the side, the downside

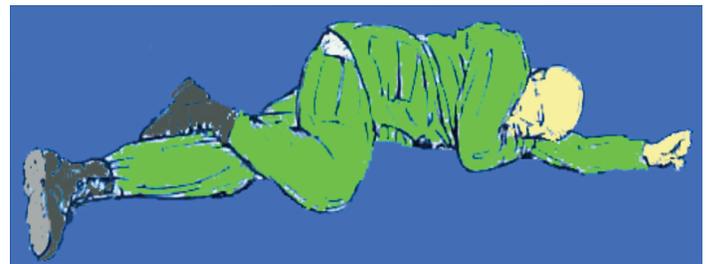


Figure 4. The Recovery Position

arm is extended, the other arm is flexed and under the head, the downside leg is extended, and the other leg is flexed with the foot behind the knee.

If the upper airway cannot be cleared, medical personnel who are trained and competent in this skill can elect to perform a surgical cricoidotomy, with a vertical skin incision.

Breathing

Check for open chest wounds, keeping in mind that you should not turn the person over to examine the back until you have ruled out pelvic fracture. If available, use a self-adhesive occlusive dressing that has an included one-way valve. Sealing

the wound is key and any non-porous material such as plastic wrap or foil can be used. If conscious, the casualty should sit up to increase intra-abdominal pressure and make it easier to breathe.

Watch for a tension pneumothorax, a true life-threatening emergency that accounts for 9 percent of the preventable casualties from blast and ballistic trauma. A tension pneumothorax exerts increasing pressure on the heart, trachea, and major blood vessels. Symptoms include increased difficulty breathing, chest pain, air hunger, increasing agitation, and increasing heart rate. The trachea is eventually displaced to the normal side, there may be cardiac arrhythmias, and there may be air bubbles under the skin (surgical emphysema).

Instant relief may be obtained with a needle thoracostomy, which paramedics are trained to do by inserting a No. 14 gauge 3¼-inch angiocath until tension is relieved, and then removing and recapping it as it may be needed again. The needle should be inserted at or lateral to the nipple line in the second intercostal space or two-to-three fingerwidths below the middle of the clavicle. The clavicular line may be difficult to determine, and decompressions are often done too medially if this is used as a landmark. Current recommendations allow for the fifth intercostal space in the anterior axillary line as an alternate site.

A Head-to-Toe Examination

Check for wounds on the front of the chest by using the “monkey claw” technique, running the hands down the body against the skin. Then gently assess for the presence of a pelvic fracture by gently squeezing together and, if no crepitus is noted, pushing posteriorly. Grasp the iliac wings and assess for anterior/posterior stability. If there is evidence of pelvic fracture, tie both the feet and the legs together and move with extreme caution. With a posterior fracture, some major blood vessels may be torn causing exsanguination into the pelvis.

Identify head and eye injuries. Protect the injured eye as with a rigid shield that does not apply pressure to the globe of the eye.

Reassess all previous efforts at hemorrhage control, and assess for shock. Loss of the radial pulse, which disappears around 80 mm/Hg, is an early sign of shock. The femoral pulse disappears around 70 mm, and the carotid pulse around 60 mm.

Contrary to common belief, elevating the legs does nothing to help shock.⁸ The best management of hemorrhagic shock is to stop blood loss and to replace lost fluids with appropriate intravenous fluid. This must be done cautiously, as bringing the blood pressure to normal is dangerous in traumatic hemorrhage. Continued fluid replacement in the face of continued internal bleeding will dilute the clotting factors.

Hypothermia

Use of blankets and thermal blankets is good, but active warming is likely to be needed. A hand warmer over the femoral

artery or under the armpits may be helpful, or simply placing the patient in direct sunlight.

“The Blow-Out Kit”

For response to blast or ballistic trauma, essential equipment includes a tourniquet such as the CAT, the MET, or the Soft-T-W; a chest seal; Curlex gauze in a S-fold or roll; a hemostatic agent; one Ace bandage for securing the pressure dressing; a nasopharyngeal airway; a No. 14 gauge 3¼-inch needle; and a small roll of duct tape. Skills such as tourniquet application, pressure application, examination for various injuries, and airway management need to be practiced.

Conclusions

Civilian situations may resemble a combat scene, and preventable deaths can be averted by use of the techniques and doctrine developed by the military and being brought into civilian practice. Anyone could be a first responder in such a situation. Patients, other medical professionals, police, and other first responders, should definitely avail themselves of training in these lifesaving procedures, and incorporate the needed equipment in their medical bags. The most current guidelines can be found at C-TECC.org.

Acknowledgement: This paper is based on a five-hour course presented at the 31st annual meeting of Doctors for Disaster Preparedness in Houston, Tex., in 2013. A recording and Power Point presentation are available; see ddponline.org/hatfill/. Geoffrey L. Shapiro, director, EMS and operational training programs, George Washington University, reviewed the manuscript and provided helpful assistance.

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