Lessons From the Military

Trunkey D. Excelsior Surgical Society Edward D Churchill Lecture. Changes in combat casualty care. *J Am Coll Surg.* 2012;214:879-891.

Recent Middle East conflicts have changed the face of war, care systems, and treatment strategies. There has been remarkable evolution to more destructive weapons epitomized by the introduction of the improvised explosive device (IED). Although land mines, booby traps, and other devices have been used to kill, maim, or cause psychological issues, IEDs are particularly noteworthy. Initially, IEDs were made up of Russian land mines left over from the 1980 war in Afghanistan. During the US war in Iraq, multiple ammunition depots were discovered but not emptied and were left unguarded. The consequence was that insurgents captured this ammunition and quickly made IEDs. The typical IED is composed of 1 to 3 of the 155-mm Howitzer shells that were altered to have a detonator that was either hooked to a telephone that could be used to explode it remotely or it was armed with a pressure switch so that when a soldier or vehicle went over the pressure switch it exploded. It is possible with a 3 Howitzer shell device to tip over a 60-ton tank. A single shell can destroy a Humvee and seriously maim or kill soldiers inside the vehicle. More recently, IEDs have been made with ammonium nitrate, which can be obtained from Pakistan, and typically contain 1,000 lb of this substance. In addition, shaped charges are obtained by insurgents from Iran.

Armor has been used in warfare since 1400 BC. Early armor consisted of leather, metal, chain mail, and steel plates. More recently, plastics have been used (Kevlar, DuPont, Wilmington, DE) with ceramic fibers. Although Kevlar was used in the first Gulf War, there were insufficient data at that time to tell whether Kevlar was effective. It was subsequently found that Kevlar did not completely protect the soldier from high-velocity rifle injuries, armor-piercing bullets, high-energy fragments from mortars and artillery, or rifle-propelled grenades. Ceramic plates were added to the Kevlar vest, but even this addition of protection is not foolproof. For example, these vests do not protect areas of the body such as the lower part of the forehead, face, upper neck, groin, lower abdomen, and, of course, both arms and legs. However, there is no question that personal armor has prevented mortality in many soldiers.

The pattern of injury has also evolved. Extremity injuries are the most common injuries treated in modern warfare. If possible, the priority is to salvage limbs and minimize the amount of tissue that must be lost. However, the axiom of life over limb is still in place. Temporizing surgical approaches including stents or shunts in the vascular bed are used to preserve the extremity until ultimate reconstruction is possible. Burn wounds can be particularly devastating and are common. Soldiers trapped in a burning vehicle may sustain 90% to 100% full-thickness burn injury with associated inhalation injury. Burns are frequently associated with traumatic amputations, which only compound mortality and morbidity. Like other combat casualties, burn patients have benefited from hypotensive resuscitation (see later). The primary resuscitation guideline is urine output, which is held at 0.5 mL/kg/h. Torso wounds are not as common compared with their incidence in other conflicts. This is because of the protective armor that each soldier wears. When torso wounds are seen, they can be caused by a blast injury in which the soldier becomes a missile as part of the initial explosion. Torso wounds may also be caused by shrapnel or debris that penetrates the armor. Blunt injuries that do not penetrate armor cause internal organ damage, particularly to the lungs, liver, kidneys, and spleen.

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Bickell WH, Wall MJ Jr, Pepe PE, et al. Immediate versus delayed fluid resuscitation for hypotensive patients with penetrating torso injuries. *N Engl J Med.* 1994; 331:1105-1109.

US military and coalition forces presently have the best casualty treatment and evacuation system in history. Tactical Combat Casualty Care, the initial field management program, originated as a special operations course and has changed the landscape of prehospital military medical care. Comparing medical fatality rates throughout recent military history, the percentages of those wounded who subsequently die has been reduced dramatically. In World War II, of the soldiers who were wounded, 19% of these victims died. In Vietnam, of those who were wounded, 15% died, and now the US casualty rate in Iraq and Afghanistan is less than 9%, likely through prehospital intervention.

Currently, extremity hemorrhage is the most frequent cause of preventable battlefield death. We can extrapolate this to civilian terrorist attacks after which extremity hemorrhage is the opportunity for lifesaving interventions in the initial few moments of a terrorist attack. If there is only 1 rescuer to bring a patient to cover in a high-risk situation, military rescuers hold the patient by the collar behind the nape of the neck and drag the patient behind the rescuer toward cover. In this way, dragging the patient behind the rescuer, a military

rescuer can maintain a "head-up" position to visualize the surrounding environment and constantly evaluate for further threats or change direction as needed.

In military history, almost 90% of all combat deaths occur before the casualty reaches a medical treatment facility. Therefore, the fate of the injured often lies in the hands of those who can provide first care. In combat, this includes care provided by medics or teammates. In a civilian mass casualty event, the onus of care relies on the help of nearby Good Samaritans who respond to the event. In the Boston bombings, Good Samaritans facilitated the application of tourniquets and the interruption of life-threatening bleeding, allowing patients to be evacuated from the site of the bomb blast effectively. A casualty with a femoral artery or femoral vein disruption can exsanguinate in as little as 3 minutes; thus, a tourniquet is a critical part of initial treatment at the point of injury. Improvised mechanisms to stop bleeding including belts, strips of clothing, or cords likely also save lives. Non–life-threatening bleeding should be ignored until the patient has been moved from the area of greatest risk. Data provided by the Army Surgeon General suggest that 1,000 to 2,000 lives have been saved in the war to date through the use of tourniquet application in the prehospital setting. It is also notable that there have been no amputations caused by prehospital tourniquet use in combat and that only 3% of patients have had transient nerve palsies from tourniquet use.

If a tourniquet is deemed to be ineffectual, a second tourniquet may be applied above the first tourniquet to control bleeding. Tourniquets do not work well over joints or other bulky items in the clothing. The mistakes to avoid with the tourniquet are not using one, using a tourniquet for minimal bleeding or putting a tourniquet on too proximally, or taking it off when the casualty is in shock or during transport. The most common mistake is that the tourniquet has not been made tight enough. The tourniquet, if applied properly, should eliminate distal pulses, and if the first application is not effective, the responder should apply a second tourniquet. If the tourniquet is applied effectively, it is extremely painful, but pain does not indicate that there has been a mistake in the application of the tourniquet and it certainly does not indicate that the tourniquet should be removed. Some wounds are located at sites where a tourniquet cannot be applied such as the neck, axilla, or groin. In these less compressible areas, topical hemostatic agents can be used to stop life-threatening bleeding. In the military, combat gauze is often used; the application of combat gauze is routinely taught to military first responders. Combat gauze is a kaolin-impregnated product that helps to activate the clotting cascade and has been shown to be an effective tool to staunch bleeding in the battlefield. To apply combat gauze, pressure must be applied over the site of bleeding for at least 3 minutes for the material to be most effective. Additional dressings can be applied over the top of the combat gauze to help quell bleeding until the patient can reach a forward surgical team.

Although tourniquets and combat gauze work effectively for external hemorrhage, they do not address internal bleeding. Technical field care guidelines now recommend the use of tranexamic acid (TXA) in casualties with hemorrhagic shock, 1 or more major amputations, penetrating torso trauma, or evidence of severe bleeding. TXA is optimally given within the first hour of injury but not after 3 hours of injury. This practice is currently supported by 2 large studies that have been discussed previously in this column (*Air Medical Journal* 2014; 33(6):246-249).

Shock evaluation and management are essential to prehospital military casualty care. Continued reassessment is paramount, and important findings include evaluation of mental status in the absence of head injury and the quality of peripheral pulses. These are the best field indicators of shock. The military uses a hypotensive resuscitation strategy in which goals of fluid administration are to improve the state of consciousness without sophisticated monitoring, and palpating the radial pulse corresponds roughly to a systolic blood pressure of 80 mmHg. In the prehospital setting, work by Bickell and others points out that in the setting of uncontrolled hemorrhage, aggressive prehospital fluid administration can compromise the victim's intrinsic ability to clot off internal bleeding by diluting clotting factors and increasing intravascular pressure to the point at which the clot is disrupted by hydrostatic force. In mass casualty events, the major goal of a first responder or primary provider is the control of bleeding, which takes precedence over infusion of resuscitation fluid. Other essential components of shock management in the prehospital setting are avoidance of exposure and hypothermia.

Airway management frequently takes precedence in civilian prehospital care. In current military directives, personnel should avoid invasive airway management while in the "care under fire" phase of an operation. A mechanical airway is never established in a casualty when a unit is under effective fire because of the risk to the unit, and, therefore, airway management is often deferred until the casualty has been moved to cover. A compromised airway is a relatively infrequent cause of death in combat, accounting for less than 1% to 2% of combat-associated fatalities. Unfortunately, in a mass casualty event, which is likely in a resource-scarce environment, the patient with no airway has a minimal chance of survival. For this reason, if there are multiple injured patients, the prevention of life-threatening hemorrhage with direct pressure or tourniquets must take priority.

Airway compromise in the civilian prehospital setting is often the result of cardiac or respiratory compromise in elderly patients with pulmonary or cardiovascular disease. In a mass casualty event, airway compromise could reflect an inhalation injury or significant maxillofacial trauma. Although intubation is emphasized, cricothyroidotomy should be available for airway management. The examination of trauma data from Iraq and Afghanistan reveals that approximately 14% of prehospital cricothyroidotomies were performed in theater after failure to intubate with rapid sequence intubation by a physician or