Tactical Combat Casualty Care and Wilderness Medicine

Advancing Trauma Care in Austere Environments

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KEYWORDS

• Tactical combat casualty care • TCCC • Wilderness medicine
• Battlefield trauma care • Tourniquets • Hemostatic dressings

KEY POINTS

- The Joint Trauma System helped the US military achieve unprecedented success in casualty survival during the wars in Afghanistan and Iraq.
- Tactical Combat Casualty Care (TCCC) is the prehospital component of the Joint Trauma System.
- Since most combat fatalities occur before the casualty reaches the care of a surgeon, TCCC plays a key role in ensuring that casualties have a maximal chance of survival.
- The realization that extremity hemorrhage, a leading cause of preventable death on the battlefield, could be effectively and safely addressed with limb tourniquets was the primary driving factor for the Special Operations medical research effort that gave rise to TCCC.
- Organizations advocating for the translation of TCCC concepts to the civilian sector include the Wilderness Medical Society, the National Association of Emergency Medical Technicians, the American College of Surgeons' Hartford Consensus working group, the White House Stop the Bleed campaign, and the Committee on Tactical Emergency Casualty Care.

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INTRODUCTION

In 1992, the Naval Special Warfare Biomedical Research and Development program undertook a review of battlefield trauma care. The primary driver for this research effort was the realization that, although extremity hemorrhage was a leading cause of preventable death in combat casualties[1,2] and tourniquets could be applied safely for short periods, tourniquet use was universally disparaged in both civilian and military prehospital trauma care.[3–5] A thorough review of battlefield trauma care recommendations at the time resulted in the development of the first set of Tactical Combat Casualty Care (TCCC) Guidelines, a set of evidence-based, best-practice trauma care guidelines designed specifically for use on the battlefield, which were published in *Military Medicine* in 1996.[3] The Wilderness Medical Society (WMS) assisted in reviewing the TCCC recommendations, reevaluating the interpretation of the available evidence that supported these recommendations, and discussing their implications for the battlefield and other austere environments.[6]

After 2001, the lessons learned from the battlefields of Iraq and Afghanistan allowed continuous refinement of the TCCC Guidelines through the efforts of the Committee on Tactical Combat Casualty Care (CoTCCC). Importantly, combat medics, corpsmen, and pararescuemen (PJs) have consistently been a strong presence in the CoTCCC.

Now, in 2016, TCCC has been well-documented to have played a major role in achieving the highest casualty survival rate in the history of modern warfare in military units that train all of their members in TCCC.[4,7–11]

TCCC is presently the standard for battlefield trauma care in the US Military and for many allied nations. CoTCCC members work closely with civilian trauma colleagues in the Hartford Consensus effort and the White House Stop the Bleed campaign to translate trauma care lessons learned on the battlefield to lives saved at home. In cooperation with the National Association of Emergency Medical Technicians (NAEMT), the CoTCCC has helped to develop TCCC-based trauma courses to assist in training civilian emergency medical services systems, fire and rescue, and law enforcement organizations in trauma care.

TACTICAL COMBAT CASUALTY CARE AND WILDERNESS MEDICINE

The wilderness environment presents some of the challenges experienced by medics on the battlefield: both patient and provider are typically in remote locations where evacuation is neither quick nor easy; there may be ongoing hazards to contend with; equipment is limited; the environment may be cold, hot, or aquatic; and the providers are often not trauma care specialists.[6,12] The extreme diversity of nature that makes the wilderness so alluring complicates the care of patients with trauma in a myriad of ways, from whitewater rescue to high-angle rescue to avalanche rescue. Although many of these challenges are distinct from those encountered on the battlefield, there is a good deal of overlap in the approach to patients in these ~~two~~ settings. A selected subset of the trauma care recommendations in TCCC and their applicability to the wilderness environment are reviewed and discussed later. The current TCCC Guidelines may be found on the Joint Trauma System (JTS) and NAEMT Web sites and in the Prehospital Trauma Life Support (PHTLS) textbook that is published every 3 to 4 years by NAEMT.[13]

APPROACH TO PATIENTS

TCCC recognizes that battlefield trauma care must combine good medicine with good small unit tactics and divides its recommendations into 3 phases: Care under Fire

(while the unit is actively taking hostile fire), Tactical Field Care (the unit and the casualty are still in a prehospital combat environment but not actively engaging the enemy), and Tactical Evacuation Care (during which time the casualty is being transported to definitive care).[3,13] In the wilderness, the terrain, environment, the location, and the nature of the activity in which the group is engaged provide variation and complexity to prehospital trauma care. An open fracture sustained during a multi-day caving expedition must be approached differently than one that occurs in an urban setting.

In both environments, the well-known ABC (airway, breathing, circulation) sequence of initial steps should be replaced with the acronym MARCH (massive bleeding, airway, respirations, circulation, and head/hypothermia.)

In patients with trauma, control of massive external hemorrhage is the most important initial step. Injury to a major vessel may result in death within as little as 5 to 10 minutes. When the hemorrhage is external, first responders have the ability to effectively intervene to stop the bleeding and should do so.

EXTERNAL HEMORRHAGE CONTROL: TOURNIQUETS

The renewed focus on prehospital tourniquet use is one example of the lifesaving potential of the TCCC Guidelines. Until recently, military medics were taught that tourniquets should be used as a last resort, if at all, to control extremity hemorrhage. During the Vietnam conflict and at the start of the war in Afghanistan, tourniquet use was strongly discouraged. As a result, preventable death from extremity hemorrhage was common. Maughon's[1] study of 2600 combat fatalities in the Vietnam conflict found that 7.4% of the deaths examined resulted from extremity hemorrhage. Kelly and colleagues'[14] 2008 study of 982 combat fatalities sustained during the early years in Afghanistan and Iraq found that the incidence of death from extremity hemorrhage as a percentage of the total was essentially unchanged from the Maughon[1] study at 7.8%. Holcomb and colleagues'[15] 2007 study of Special Operations fatalities noted that 3 of the 12 potentially preventable deaths were from extremity hemorrhage. These findings prompted the US Special Operations Command TCCC Transition Initiative in 2005, which expedited the fielding of tourniquets and hemostatic dressings to deploying Special Operations units.[16] As a result, tourniquet and hemostatic dressing use increased in Afghanistan and Iraq and extremity hemorrhage deaths decreased.[4] Eastridge and colleagues'[9] 2012 study of 4596 US combat fatalities from 2001 to 2011 noted that only 2.6% of total combat fatalities resulted from extremity hemorrhage; a 67% decrease.[4,9,17] Kragh and colleagues'[18,19] landmark studies in 2008 and 2009 documented that extremity tourniquets saved lives and did not result in loss of limbs caused by tourniquet ischemia.

Tourniquets have proved to be lifesaving in the civilian and wilderness sectors as well.[20–22] If a person attacked by an animal or a climber with an open fracture sustains a vascular injury with massive external hemorrhage, immediate application of an extremity tourniquet is required. The first responder then has time to convert the tourniquet to other methods of hemostasis when feasible.[23]

EXTERNAL HEMORRHAGE CONTROL: HEMOSTATIC DRESSINGS

When external hemorrhage occurs at sites that are not amenable to tourniquet use, another modality for achieving control of bleeding is the use of hemostatic dressings. The current TCCC Guidelines recommend Combat Gauze as the hemostatic dressing of choice and Celox Gauze and ChitoGauze as alternative choices. All of these hemostatic dressings should be applied with at least 3 minutes of firm, direct pressure.[13,24–29]

Combat medics on the CoTCCC have consistently expressed a strong preference for gauze-type dressings rather than powdered or granular hemostatic agents, especially for wounds in which the bleeding vessel is at the bottom of a narrow wound tract. Gauze-based hemostatic dressings are more easily packed into the depths of such wounds where they can make direct contact with the bleeding vessel. Further, powdered or granular agents may present an ocular hazard if used in a windy environment or in the presence of rotor wash from helicopters. The Israeli Defense Force has reported excellent success in treating external hemorrhage in their combat wounded with Combat Gauze.[30]

Zietlow and colleagues[20] described the Mayo Clinic experience with Combat Gauze in civilian trauma, reporting a 95% success rate after the failure of standard dressings. Both TCCC-recommended tourniquets and hemostatic dressings should be included in all wilderness first aid kits.

THE PREHOSPITAL TRAUMA AIRWAY

In trauma, managing the airway entails different considerations than those encountered in medical patients. Most airway fatalities in combat are related to direct maxillofacial trauma.[31] Endotracheal intubation in the traumatized airway is challenging, even for experienced intubationists, and most military medics have little experience in intubating patients with airway trauma. Airway trauma on the battlefield is often best managed by allowing the casualty to maintain the sit-up-and-lean-forward position if the patient is conscious and able to do so. This position allows gravity and the patient's protective reflexes to maintain a patent airway.[13] The use of supraglottic airways in the prehospital setting is increasing, but these devices have not been well studied in trauma.

When the measures discussed above do not provide an adequate airway in a casualty with direct trauma to the maxillofacial region, a surgical airway is the intervention of choice.[13,32,33] Combat medics have been shown to be able to perform this procedure with 100% success in a cadaver model when they are well trained and use a CricKey device, which is the recommended device in TCCC.[32,34]

Should the need to secure the airway arise from unconsciousness secondary to traumatic brain injury (TBI) or hemorrhagic shock, nasopharyngeal airways (NPAs) have proved to be a good option.[13] The NPA is an easily trained intervention and no airway fatalities were identified in the 2010 Mabry and colleagues[31] review of this topic as being caused by NPA failure in nontraumatized airways.

In the wilderness setting, a lower incidence of direct maxillofacial trauma and a higher incidence of unconsciousness caused by TBI would be expected. Thus the use of an NPA is a good option in wilderness settings in which a skilled and equipped intubationist is not typically present. A surgical airway remains the emergent airway of last resort for patients with trauma in the wilderness.[35,36]

RESPIRATIONS/BREATHING

Tension Pneumothorax

In the Vietnam conflict, tension pneumothorax was reported to be the second leading cause of preventable battlefield death.[2] The incidence of death has decreased with the use of body armor that provides significant (but not complete) protection to the chest and back. In addition, combat medical personnel are now taught to use needle decompression (NDC) aggressively to treat suspected tension pneumothorax. The Eastridge and colleagues[9] study noted that tension pneumothorax comprised only

0.2% of deaths among US combat fatalities, which represents a decrease of more than 90% in preventable deaths from this cause.[13]

Current TCCC Guidelines call for casualties who have progressive respiratory distress following torso trauma to be suspected of having a tension pneumothorax and considered for NDC on the side of the injury with a 14-gauge, 8-cm (3.25-inch) needle/catheter unit. NDC is performed at the second intercostal space at the midclavicular line or the fourth or fifth intercostal space at the anterior axillary line. Needle entry into the chest should not be medial to the nipple line and the needle should not be directed toward the heart.[13]

Use of an 8-cm (3.25-inch) needle rather than the previously used 5-cm (2-inch) needle was introduced after the Harcke and colleagues[37] article in 2008. Those investigators noted that several of the cases in their autopsy series had failed attempts at NDC because the needle/catheter units used for the procedure were too short and did not reach the pleural space. This observation was followed by a virtual autopsy computed tomography (CT) study of chest wall thickness that found a mean chest wall thickness of 5.36 cm in the 100 military fatalities studied. Harcke and colleagues[37] recommended that an 8-cm (3.25-inch) needle/catheter unit be used for NDC in order to achieve a 99% assurance of reaching the pleural space.[37] Other investigators have presented similar findings and concerns.[38,39] Harcke and colleagues'[37] findings led to the TCCC recommendation to use an 8-cm (3.25-inch), 14-gauge needle/catheter unit inserted to the hub.[13] The authors are unaware of any reports of death from tension pneumothorax in US combat casualties caused by failed NDC since this change was made almost a decade ago.[13] Bilateral NDC should be performed before resuscitation efforts are abandoned when a casualty with torso trauma or polytrauma has a prehospital cardiopulmonary arrest.[13]

In the wilderness setting, death from tension pneumothorax is expected to be less common, although penetrating chest trauma may occur from hunting accidents and blunt chest trauma may result from falls, avalanche, or mountain bike accidents. Inclusion of an 8-cm (3.25-inch), 14-gauge needle in wilderness medical kits is a reasonable measure in order to be able to perform NDC in the unlikely event that this uncommon but life-threatening disorder is encountered in the wilderness. Improved success using an 8-cm (3.25-inch) needle (83%) compared with a 5-cm (2-inch) needle (41%) was reported by the Mayo Clinic.[40] No complications were reported with either length needle.

Open Pneumothorax

An open pneumothorax (also sometimes referred to as a sucking chest wound) may result from a penetrating injury to the chest wall. When the defect in the chest wall is sufficiently large (usually two-thirds or more of the diameter of the trachea), air preferentially flows into the chest cavity via the defect in the chest wall, instead of into the lung via the trachea, as the casualty inhales. Air entering through the defect in the chest wall allows the lung on the affected side to collapse and impairs oxygen exchange.[13]

Although there is little evidence that an open pneumothorax by itself (ie, without injury to underlying lung tissue and major vascular structures), is a potentially lethal injury,[9,41] the impaired pulmonary gas exchange could potentially result in pulmonary compromise in a polytrauma casualty and contribute to secondary hypoxic brain injury in casualties with TBI.[13]

Treatment of an open pneumothorax consists of applying a vented occlusive chest seal over the defect in the chest wall, thus preventing air from entering the pleural space through the defect in the chest wall.[41] The vent in the chest seal prevents the development of a tension pneumothorax in the presence of an underlying lung injury

and air leak. Commercially available vented and nonvented chest seals have been evaluated in animal studies.[42,43] In the Kheirabadi study, chest seals were applied and then 200-mL increments of air were injected into the pleural cavity of thoracotomized swine every 5 minutes until either tension pneumothorax developed or the volume of air injected equaled 100% of the animal's estimated total lung capacity.[42] Tension pneumothorax did not develop in animals treated with vented chest seals (incorporating a 1-way valve that allowed air to leave but not to enter the pleural space). However, tension pneumothorax did occur in the animals with chest seals without valves. Vented chest seals, then, are preferred for the prehospital management of open pneumothorax, to be followed by tube thoracostomy when time, skills, and circumstances allow.[13,41]

For wilderness medicine providers, open pneumothorax and the need for a vented chest seal is an injury pattern that might result from gunshot wounds sustained in hunting accidents. This injury, in the setting of delays to evacuation, is one that should be treated with prophylactic antibiotics, as described later.

INTRAVENOUS AND INTRAOSSEOUS ACCESS

It has been a long-standing prehospital trauma care practice to establish intravenous (IV) access for individuals with significant trauma. TCCC has reconsidered this intervention. Starting IV lines inflicts significant cost in both time and logistics and may delay a combat unit's ability to maneuver when needed. TCCC recommends that IV lines be started only for individuals who require fluid resuscitation as a result of hemorrhagic shock or who need IV medications, especially tranexamic acid (TXA) or analgesics. IV lines are easily dislodged, especially during combat operations. The TCCC curriculum describes a technique developed by medics in the 75th Ranger Regiment that helps to ensure that IV lines are not dislodged during casualty movement.[13,44]

INTRAOSSEOUS ACCESS

Establishing IV access is a fairly easy procedure unless the patient is obese, a small child, or in shock, or the person attempting to start the IV does not perform this procedure routinely. However, the last 2 caveats often apply to the battlefield setting. Another way to achieve vascular access is to use an intraosseous (IO) device.[45,46]

This technique is easily trained[47] and can be performed by prehospital providers with a high rate of success.[48] Because the technique is performed based on bony landmarks rather than by visualizing peripheral veins, it is more easily performed under low light and night vision device conditions.[13] The IO approach was proposed by TCCC as an alternative to IV lines on the battlefield in 2002 and quickly became widely used by combat medical personnel because the procedure is quickly and easily performed. IO access is now a widely used technique in the civilian sector as well.[49] The Pyng FAST-1 and the EZ-IO devices have been the most widely used by the US Military in the recent conflicts.[13] Although the risk of osteomyelitis is very low and the authors are unaware of any reports of this complication from the conflicts in Iraq and Afghanistan, both the potential for infection and the patient discomfort experienced with an IO procedure make using peripheral IV access the option of first choice when circumstances allow.

For practitioners of wilderness medicine, the indications for IV and IO access are basically the same as for the battlefield, except that it may be less common for medical providers in the wilderness setting to be prepared to perform fluid resuscitation from hemorrhagic shock.

TRANEXAMIC ACID

Noncompressible hemorrhage is the leading cause of preventable death in combat casualties.[9] The large, prospective, randomized Clinical Randomization of an Antifibrinolytic in Significant Hemorrhage (CRASH-2) study examined the effect of TXA administration in trauma patients at risk of bleeding and documented a small but statistically significant survival benefit. Although deep venous thrombosis is a known complication of trauma, there was no increase in the rate of vascular occlusive events in the TXA group.[50] The subsequent subgroup analysis of the CRASH-2 data focused on deaths caused by bleeding rather than all-cause mortality and examined the effect of the timing of TXA administration on outcomes. The greatest benefit of TXA administration was obtained when the medication was given within 1 hour of the time of injury. TXA administered between 1 and 3 hours after the time of injury also reduced the risk of death caused by bleeding. However, TXA administered later than 3 hours after injury was observed to increase the risk of death from exsanguination.[51]

The Military Application of Tranexamic Acid in Trauma Emergency Resuscitation Study (MATTERS) was performed at a role 3 facility in Afghanistan.[52] The MATTERS investigators found a decreased mortality among combat casualties who received TXA, despite their being more seriously injured. In the subgroup of casualties who received massive transfusions (more than 10 units of red cells within the first 24 hours), mortality in the TXA group was markedly lower (14.4%) compared with the control group (28.1%). The CRASH-2 and MATTERS findings both supported the use of TXA in combat casualties who are either in hemorrhagic shock or at significant risk of that condition. As a result of these two studies, TXA was added to the TCCC Guidelines in 2011.[53]

A subsequent report found a benefit from administering TXA in the prehospital setting.[54] Studies examining the effect of giving TXA before elective surgical procedures associated with significant blood loss have consistently found that TXA reduces blood loss in these procedures and does not increase the risk of deep venous thrombosis.[55] TXA is recommended in the TCCC Guidelines for casualties who are anticipated to need significant blood transfusion (eg, casualties with hemorrhagic shock, 1 or more major amputations, penetrating torso trauma, or evidence of severe bleeding.)[44] The recommended dose is 1 g of TXA in 100 mL of normal saline or Lactated Ringers solution. TXA should be infused over 10 minutes to avoid the risk of hypotension and should be given as soon as possible after injury but not later than 3 hours after injury. In the event that evacuation to a medical treatment facility is delayed, a second infusion of 1 g of TXA should be administered after fluid resuscitation has been performed.[13]

In the wilderness environment, TXA administration should be considered for trauma patients in shock, as well as those with penetrating torso trauma, severe external hemorrhage, or blunt trauma with suspicion of non-compressible hemorrhage. Falls and TBI are common in the wilderness and the value of TXA in reducing intracranial hemorrhage is currently an area of active investigation.

FLUID RESUSCITATION FROM HEMORRHAGIC SHOCK

Hemorrhagic shock is the most common cause of potentially preventable death on the battlefield.[9] In the hospital setting, hemorrhagic shock is treated by resuscitation with blood or blood components until adequate tissue perfusion is restored. A large, prospective, randomized study at Ben Taub Hospital in Houston examined the benefit of early, aggressive fluid resuscitation in patients with penetrating torso trauma and shock.[56] This study found that early fluid resuscitation group had decreased survival

as compared to the group of patients in whom fluid resuscitation was delayed until after surgical hemostasis had been achieved.[56] TCCC originally recommended that fluid resuscitation for casualties with shock from noncompressible bleeding sites be delayed until after surgical control of the bleeding and that 1000 mL of Hespan be used to resuscitate casualties in shock from external bleeding sites after hemorrhage control.[3]

However, in 1999, subject matter experts reviewing battlefield trauma care issues from the Battle of Mogadishu recommended that casualties who were experiencing unconsciousness or mental status changes caused by hemorrhagic shock should be fluid resuscitated to an end point of improved mentation, even in the presence of ongoing noncompressible (internal) hemorrhage.[57] Further recommendations from subsequent Department of Defense (DoD) fluid resuscitation workshops on fluid resuscitation led to a single hypotensive fluid resuscitation strategy for combat casualties in shock, whether their hemorrhage was controlled or uncontrolled. The synthetic hetastarch solution Hextend replaced the previously used Hespan because of the former solution's lesser impact on coagulation status.[58,59]

Both of the strategies mentioned earlier made the implicit assumption that blood products would not be available in the tactical field care phase of combat casualty care. In the ensuing years, a number of events have occurred: (1) the value of whole blood as the preferred fluid for fluid resuscitation has been documented[60–63]; (2) transfusing red blood cells in a 1:1 or 1:1:1 ratio with plasma and platelets has been shown to be superior to a transfusion strategy using a predominance of RBCs[64,65]; (3) large volumes of crystalloid have been shown to worsen outcomes in patients with trauma,[66,67]; (4) questions have been raised about the safety of using hetastarch solutions in critically ill patients[68,69]; (5) both military units and civilian trauma systems have shown that blood products can be used in the prehospital setting[61,70–77] and that this practice improves casualty outcomes[74]; and (6) a preponderance of the literature has found that plasma resuscitation is a better choice for resuscitation than either crystalloids or colloids.[78,79] Accordingly, a recent review of fluid resuscitation options in TCCC has recommended a preference list of options for fluid resuscitation, going from the most desirable (whole blood) to the least desirable (crystalloids).

In the wilderness setting, as with ground-based combat medical personnel, blood components are unlikely to be readily available. In this circumstance, the best strategy for treating hemorrhagic shock is hypotensive resuscitation using a reconstituted dried plasma product. Although dried plasma products (French FyLP or German LyoPlas) have been used widely by coalition forces in Afghanistan and Iraq, they are not currently approved by the US Food and Drug Administration for use in the United States (Butler FK: Fluid resuscitation in tactical combat casualty care – yesterday and today. Submitted for publication to *Wilderness and Environmental Medicine*).[78] As long as dried plasma remains unavailable in the United States, if a prolonged evacuation is anticipated, Hextend will provide a more sustained intravascular volume expansion than crystalloids.[80]

HYPOTHERMIA AND COAGULOPATHY ON THE BATTLEFIELD

As noted previously, hemorrhage is the leading cause of preventable death in combat casualties. Hypothermia may contribute to the coagulopathy of trauma by decreasing platelet function, decreasing the activity of enzymes in the coagulation cascade, and causing alterations of the fibrinolytic system.[81,82] Hypothermia (defined as a core temperature <36°C) was present in 18% of 2848 combat casualties and was an independent predictor of mortality.[83] Hypothermia may occur even in warm environments and

may be exacerbated by long evacuation times, helicopter transport, and wet clothing. Hemorrhagic shock also contributes to hypothermia by reducing the body's ability to produce metabolic heat.[13]

The body temperature in combat casualties should be maintained as close to 37°C as possible,[84] Hypothermia prevention should be started early in the management of combat casualties, after external hemorrhage has been controlled and TXA administered, if indicated. The casualty should be protected against the environment to the greatest extent possible. Clothing should be retained where that is consistent with treating injuries. Conductive heat loss should be prevented by not having the casualty lying directly on the ground or on the floor of an evacuation helicopter. Personal protective equipment should be kept on or with the casualty as feasible. After massive hemorrhage has been controlled, the airway opened, and breathing difficulties addressed, wet clothing should be removed and replaced with dry clothes, if feasible.

TCCC recommends the Hypothermia Prevention and Management Kit (HPMK) to minimize heat loss in combat casualties. The HPMK combines an active heating device (the Ready-Heat blanket) with a passive device (the Heat Reflective Shell) to produce a synergistic heat-conserving effect for the casualty. The HPMK has been shown in United States Army Institute of Surgical Research testing to effectively prevent heat loss.[85] Care should be taken to place the Ready-Heat blanket over the uniform shirt, not directly on the skin, because the device may cause burns if placed on bare skin.

If purposed hypothermia prevention devices are not available, then blankets, ponchos, sleeping bags, or other items at hand should be used to keep the casualty as warm and dry as possible. Controlling hemorrhage and providing adequate fluid resuscitation, with blood components if possible, will restore tissue perfusion and help to maintain the casualty's ability to generate metabolic heat.

The HPMK or similar devices may be very useful in the wilderness, but often are not available. Extra clothing, sleeping bags, insulating blankets, and other items may be more readily available and should be applied in layers to achieve effective hypothermia prevention for patients with trauma in the wilderness.

The WMS Practice Guidelines for the prevention and treatment of hypothermia offer additional treatment options and perspectives.[86]

EYE TRAUMA

Penetrating eye injuries are frequently encountered on the battlefield, especially when exposed to improvised explosive devices (IEDs) with small rock or metallic items embedded in the device to increase the incidence of fragment injuries from the blast. Providers should have a heightened index of suspicion in the presence of multiple punctate facial wounds (peppering). When injury to the globe is suspected, first-responder management of these injuries includes a rapid field evaluation and documentation of vision, covering the injured eyes with a rigid eye shield, and prompt administration of TCCC-recommended antibiotics. Eye shields are essential in this setting but have been reported to be underused in the management of eye injuries during the recent conflicts.[87] If no rigid eye shield is available, a set of protective eyewear will serve this purpose well. A point of emphasis is that pressure patches and other dressings that may come into direct contact with an injured eye should be avoided.[13] Also, avoid manipulating the eye during evaluation and treatment in any way that might increase intraocular pressure and result in the expulsion of intraocular contents through the corneal or scleral defect.[13,88] Moxifloxacin 400 mg once a day, given immediately after injury, is the antibiotic of choice in the

prehospital environment. This medication has good coverage of the typical causative organisms for intraocular infections and penetrates well into the vitreous cavity. No topical antibiotics (ointments or eye drops) should be used on an unrepaired penetrating injury of the eye.[13,88]

Wilderness medicine practitioners are unlikely to encounter any IEDs, but may have to treat patients with fishhook or impaling thorn injuries to the eye. In both cases, the most important additional point of management is not to try to remove the fishhook or thorn.[88] Wilderness patients with known or suspected penetrating eye injuries should be evacuated as soon as feasible. A more complete discussion of the management of eye injuries and medical disorders in a wilderness setting may be found in the new seventh edition of Auerbach's[88] *Wilderness Medicine* as well as the WMS practice guidelines for eye injuries.[89]

ANALGESIA

At the onset of the Afghanistan conflict, the state of the art for battlefield analgesia in most of the US Military was the same as it had been at the Battle of Bull Run in the US Civil War.[13,90] Intramuscular (IM) morphine was the primary medication used to relieve the pain of combat wounds despite that fact that it is very slow-acting and prolongs the casualty's pain.[3] This, in turn, increases the likelihood of repeated dosing and eventual overdose.[91] Early adopters of TCCC in 2001 were using morphine administered intravenously for rapidity of analgesia and improved ability to titrate the dosage administered.[3]

After demonstration that oral transmucosal fentanyl (OTFC) could safely provide rapid and powerful analgesia in combat casualties without the need to establish an IV, this medication was added to the TCCC Guidelines.[92,93] Wedmore and colleagues[94] subsequently provided additional documentation of the safety of OTFC on the battlefield. OTFC had been recommended for use in wilderness settings as early as 1999.[95]

Ketamine is an excellent analgesic alternative for casualties either in, or at risk of, hemorrhagic shock because this medication does not cause hemodynamic or respiratory depression. Ketamine was added as an analgesic option in TCCC in 2012.[90]

In 2014, the TCCC triple-option analgesia approach to battlefield analgesia was developed. This concept originated at the direct request from combat medical personnel that the CoTCCC provide them with an inclusive but simplified approach on how best to use the available options for analgesia.[17] Thus, oral medications (acetaminophen and meloxicam, a platelet-sparing nonsteroidal analgesic) are recommended for analgesia when pain is not severe and the casualty can continue to function effectively as a combatant for his or her unit. When there is more severe pain, but the casualty is not in, or at significant risk for, shock, OTFC is the analgesic of choice. If there is moderate to severe pain, and the casualty is in shock, or at risk of shock or pulmonary compromise, ketamine is the agent of choice.[92] Ondansetron is recommended for the nausea and vomiting that may result either from opioid administration or from the combat wounds.[96]

The TCCC triple-option analgesia approach lends itself well to the wilderness environment. A practice guideline that mirrors the TCCC triple-option approach was recently approved by the American College of Emergency Physicians.[97] The WMS practice guidelines for pain management also include a discussion of the analgesic options noted earlier.[98]

ANTIBIOTICS

Open combat wounds are prone to infection and are a late cause of morbidity and mortality in combat casualties.[99] Antibiotics are indicated for combat trauma and should be

started as soon as feasible. Fourth-generation oral fluoroquinolones are the prehospital antibiotic of choice when the casualty is able to take oral medications.[99] The current recommendation is 400 mg of moxifloxacin when oral medications are feasible and IM or IV ertapenem when the casualty is not able to take oral medications.[13,44,100] Both antibiotics were selected because of their excellent spectrum of activity and their minimal serious adverse effects. In addition, moxifloxacin has excellent bioavailability when taken orally and both medications penetrate well into the vitreous cavity, which is important in treating casualties with penetrating eye injuries.

For injuries that occur in the wilderness environment, as in combat, evacuation is likely to be delayed and oral or parenteral antibiotics are indicated for any trauma that includes infection-prone injuries such as open fractures or animal bites.

TRAUMATIC CARDIOPULMONARY ARREST

Although cardiopulmonary resuscitation (CPR) has been lifesaving in patients with nontraumatic cardiac arrest, CPR is much less likely to be successful in victims of traumatic cardiac arrest.[101–103] On the battlefield, performing CPR on casualties in cardiac arrest may result in additional lives lost as combat medical personnel are exposed to hostile fire while performing CPR and care is withheld from casualties with potentially survivable wounds. In addition, delays in unit movement in order to perform CPR may result in mission compromise.[3,13] CPR should be considered in the tactical prehospital setting only if the arrest is associated with hypothermia, near drowning, or electrocution, or when the casualty is in the tactical evacuation phase of care and arrival at a medical treatment facility is imminent.[13,104] Unrecognized tension pneumothorax is a potentially reversible cause of traumatic cardiac arrest in combat casualties. Any combat casualty who sustains torso trauma or polytrauma and is found to have no pulse or respirations should have bilateral needle decompression performed to ensure they do not have a tension pneumothorax before discontinuation of care.[13,104]

DOCUMENTATION OF CARE

The lack of adequate documentation of prehospital care rendered to US casualties in Iraq and Afghanistan is problematic in ensuring optimal care for casualties and has been a clear obstacle to CoTCCC and Joint Trauma System efforts to improve TCCC.[105] The TCCC Card was developed by the 75th Ranger Regiment to document prehospital care and was adopted by TCCC in 2008. This card is simple, cost-effective, and easily fielded. It has been used widely throughout the wars in Iraq and Afghanistan and is now approved for use throughout the DoD. The recently updated TCCC card allows for a casualty Battle Roster Number (to link the casualty to the DoD Trauma Registry), provides better definition of the mechanism of injury, improves the documentation of tourniquet and hemostatic dressing use, and contains a space for types and doses of analgesics used as well as for several other commonly used elements of combat casualty care.

The TCCC card is commercially available on ruggedized paper stock that enables it to be used with reduced incidence of becoming damaged or unreadable in the harsh combat environment. Documentation of care is an important aspect of caring for casualties in the wilderness as well and either a TCCC card or some other durable record of care should be maintained throughout the time that the patient is receiving prehospital care and subsequently should be transported with the patient to the treating hospital.

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