FUNDAMENTALS OF COMBAT CASUALTY CARE

Chapter 3

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Introduction

Over the past century, an evolution in combat casualty care (CCC) has occurred. As the current century unfolds, we expect even more remarkable advances as increasing resources are focused on the out-of-hospital phases of emergency care. In addition to the development of new resuscitation strategies, surgical techniques, pharmaceuticals and other adjuncts, the military and emergency medicine communities continue to champion innovation in first responder and combat medic training and seek the means to provide effective medical direction to the incipient "Combat Emergency Medical Services (EMS) system."[1]

From its earliest days, the process of evacuating the sick and wounded from the battlefield resulted in displays of great sacrifice, bravery, and all too often, tragic errors of both omission and commission. In most cases, current practices have evolved from the on-the-job experiences of CCC providers. Clinical and treatment data in the out-of-hospital arena remain sparse, with minimal granularity consisting of occasional after-action reports bolstered by sporadic field medical records. Civilian sector solutions and training paradigms are often extrapolated and applied to the tactical setting, but translate into suboptimal tactical and clinical outcomes.[2]

Leading Causes of Preventable Death

The Wound Data and Munitions Effectiveness Team (WDMET) study provided one of the first objective databases from which inferences regarding evacuation and en-route-care were drawn.[3] Building on the WDMET concept, the Joint Theater Trauma Registry (JTTR) was developed by the United States (US) Army Institute of Surgical Research in partnership with the US Air Force and US Navy, in response to a Department of Defense directive to capture and report battlefield injury.[4] The JTTR is designed to facilitate the collection, analysis, and reporting of CCC data along the continuum of care and to make this data accessible to healthcare providers engaged in the care of individual patients, as well as for system analysis and quality improvement. While implementation of the JTTR has been successful from the point of initial surgical intervention back to rehabilitative care, success in collection of the out-of-hospital components of the registry has been more elusive. Factors limiting consistent, systematically standardized and complete out-of-hospital data collection include: (1) legacy data collection methods (handwritten documents and antiquated field medical treatment cards); (2) lack of a complementary out-of-hospital component of the Joint Theater Trauma System; and (3) lack of a standard requirement for reporting out-of-hospital casualty care clinical records.

Recent studies confirm many of the WDMET findings, with evidence that compressible hemorrhage, tension pneumothorax, and airway and ventilatory compromise, are the leading causes of preventable death in Operation Enduring Freedom (OEF) and Operation Iraqi Freedom (OIF).[5,6] The WDMET study identified the following three conditions as primary causes of preventable death on the battlefield: (1) airway obstruction (6 percent), (2) tension pneumothorax (33 percent), and (3) hemorrhage from extremity wounds (60 percent). Analysis of autopsy records from OIF indicated a frequency of preventable battlefield death between 10 to 15 percent from airway obstruction and 33 percent for extremity hemorrhage thought to be preventable by tourniquet application.[6] In a smaller study describing 12 potentially preventable deaths in special operations forces, Holcomb et al. reported the following six conditions as potential contributors to death: noncompressible hemorrhage (eight deaths), tourniquet-amenable hemorrhage (three deaths), "non-tourniquetable" hemorrhage (two deaths), tension pneumothorax (one death), airway obstruction (one death), and sepsis (one death).[5] One death was deemed due to dual conditions. To affect survival, it is critical to recognize and treat most of these conditions within the first minutes after wounding.[7] Only combatant first responders, combat medics, and other far-forward clinicians can deliver this timely care.

> Compressible hemorrhage, tension pneumothorax, and airway and ventilatory compromise are the leading causes of preventable death in OEF and OIF.

Despite the relative simplicity of the maneuvers required to treat these conditions, they remain a significant cause of mortality. This underscores the need to ensure clinical competence among CCC providers, including combatant first responders, medics, corpsmen, physicians, physician assistants and nurses, as well as an effective means of capturing clinical data in the out-of-hospital setting.[8] Gerhardt et al. recently studied the impact of deploying emergency medicine specialty-trained CCC providers including an emergency physician, an emergency medicine physician assistant, and advanced-scope-of-practice combat medics. The study demonstrated a 7.1 percent case fatality rate as compared to the concurrent theater aggregate US case fatality rate of 10.5 percent. This occurred despite a battle casualty rate nearly three times that of the contemporaneous combat theater-wide rate, an out-of-theater evacuation rate over twice that of the theater aggregate rate, and an equivalent injury severity score (ISS) to that of the theater aggregate. No deaths were attributed to airway obstruction or tension pneumothorax. One case of potentially compressible hemorrhage following traumatic lower extremity amputation resulting in death was reported.[9]

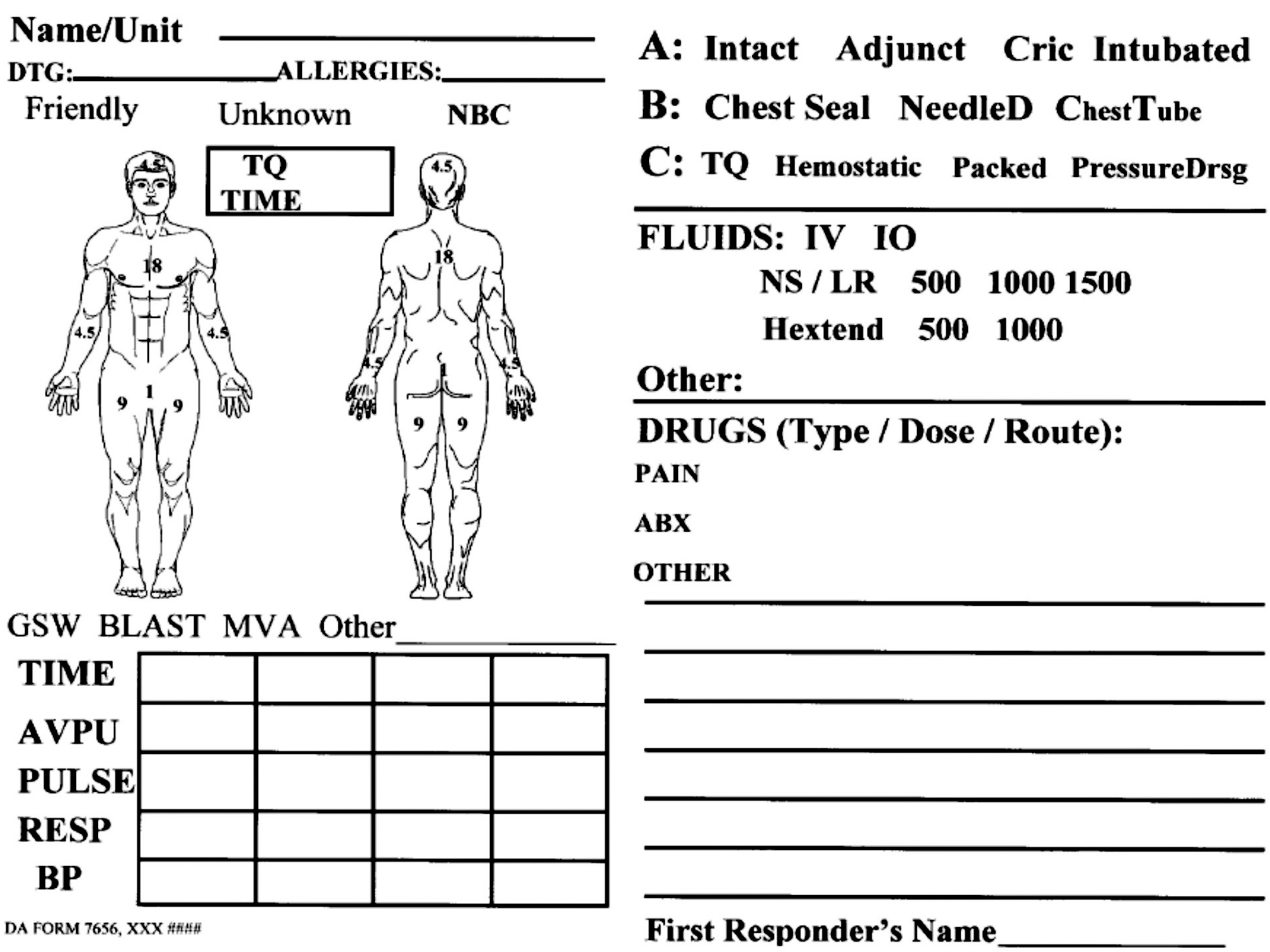
The Defense Health Board's Committee on Tactical Combat Casualty Care (TCCC) recently developed and promulgated coherent guidelines for those who engage in out-of-hospital CCC.[10] To the extent possible, the guidelines were created using literature-based evidence, rather than solely relying upon expert consensus. The importance of fully understanding TCCC principles and guidelines is underscored by the following case study.

Case Study: Out-of-Hospital Care

A combat engineer section with attached civil affairs and medical personnel mounted in up-armored High-Mobility Multipurpose Wheeled Vehicles (HMMWVs) is conducting civil-military operational activities in a semipermissive section of a large urban center in US Central Command (CENTCOM) Area of Responsibility. The three-vehicle patrol halts along an alternate supply route after visually identifying an unexploded artillery shell. Several soldiers dismount. Moments later, the convoy comes under effective fire from a four-man team of insurgents armed with a light machine gun, a rocket-propelled grenade (RPG) launcher, and two assault rifles. One vehicle is disabled by an RPG. A second RPG is launched and strikes the unit's combat medic at an oblique angle, ricocheting off his individual body armor small arms protective insert and detonating after striking the ground near his feet. The medic sustains shrapnel wounds to the right medial thigh and right forearm, in addition to blunt chest trauma. A combat engineer is also wounded with shrapnel in his right forearm. Both casualties have brisk bleeding from their forearm wound sites. As the medical officer and other soldiers approach the wounded, the RPG gunner rises again, preparing to fire at them.

What actions should be taken in this vignette? Combatants are often faced with similar scenarios. Rapid action, decision making, and technical performance of interventions are critical. In this scenario, the appropriate immediate response would be to return effective fire to suppress or neutralize the threat (i.e., enemy combatant RPG gunner). Once the tactical situation allows, hasty (rapidly applied) tourniquets should be placed proximal to both respective forearm wounds. The tourniquets should be rapidly applied over casualties' clothing in care-under-fire scenarios. Additional casualties who are unable to ambulate independently should be extricated and moved to an area of cover.

Upon reaching the relative safety of cover, the CCC provider should assess casualties for airway patency, adequate ventilation, type and severity of chest trauma, and tourniquet efficacy. A brief survey of the casualties for additional (undiscovered) wounds should be quickly performed. Suspected tension pneumothorax is treated by needle thoracostomy. If tactical conditions permit, previously applied tourniquets should be reassessed for efficacy. Such tourniquets should be more deliberately positioned



Name/Unit ____________________

DTG:____________ALLERGIES:__________

Friendly Unknown NBC

TQ TIME

4.5 18 4.5 4.5 1 9 9

4.5 18 4.5 4.5 9 9

GSW BLAST MVA Other____________

TIME				
AVPU				
PULSE				
RESP				
BP				

DA FORM 7656, XXX ####

A: Intact Adjunct Cric Intubated

B: Chest Seal NeedleD ChestTube

C: TQ Hemostatic Packed PressureDrsg

FLUIDS: IV IO

NS / LR 500 1000 1500

Hextend 500 1000

Other:

DRUGS (Type / Dose / Route):

PAIN

ABX

OTHER

First Responder's Name____________

Figure 1. *TCCC casualty treatment card (DA 7656).*

directly proximal to the wound over bare skin. If, upon further examination of the casualty, a tourniquet is believed unnecessary, extremity wounds can be treated with standard or hemostatic wound dressings. This is followed by administration of prophylactic antibiotics and analgesics. During the ongoing process of assessment and tactical field care, appropriate tactical evacuation should be arranged. The CCC provider should continue to monitor and treat casualties during casualty evacuation. A TCCC casualty treatment card (DA 7656) should be completed at the earliest possible juncture, and it should be submitted to the appropriate authority (Fig. 1). Lastly, upon arrival at the receiving facility or upon transfer to the evacuation conveyance, the CCC provider should verbally sign over care (e.g., briefly summarize injuries and care) of casualties to receiving medical personnel.

Combat Versus Civil Sector Out-of-Hospital Care

While some similarities exist, out-of-hospital care in combat settings often radically differs from civil sector practice in the US. Beyond the challenges of individual patient care, harsh weather conditions, and austere settings, out-of-hospital careproviders face unique tactical challenges. For example, in civilian sector emergency medical services (EMS), a typical motor vehicle collision scene might include an ambulance crew routinely consisting of two or even three emergency medical technicians (EMTs), with at least one being an EMT-Paramedic. Often, firefighters will be present, providing additional capabilities. Ambulances will be stocked with a wide array of basic and advanced life support devices, monitors, and pharmaceuticals. First responders will have telecommunication capacity and some form of medical direction for decision support and destination guidance. In the majority of cases, significant resources will be brought to bear upon one or two patients. In addition, civilian sector out-of-hospital careproviders do not typically face hostile gunfire and are able to fully focus on patient care.

Though some similarities exist, out-of-hospital care in combat settings often differs radically from civil sector practice in the US.

In contrast to the aforementioned scenario, one may envision a combat medic or other careprovider responding to casualties after a roadside bomb detonates adjacent to their convoy. After exiting his or her vehicle, the first responder proceeds on foot to the scene. Usually, all available medical equipment is carried by the medics themselves in a rucksack or otherwise harnessed to them. There is likely to be only one medic assisting casualties that were injured by a combination of high-explosive ordnance, vehicle fires, or small-arms fire. The medic is appropriately focused on patient care but must also be cognizant that the overarching priorities are the combat unit's integrity and mission. While working, the medic may become the target of hostile fire and may have to return fire.

Figure 2. *Medical evacuation (MEDEVAC) of an injured soldier onto a UH-60 Black Hawk helicopter in Afghanistan. Evacuations tend to be longer in distance, duration, and complexity as compared to civilian settings. Image courtesy of Defense Imagery Management Operations Center (DIMOC).*

As highlighted previously, TCCC poses additional unique challenges compared to civilian practice. Combat casualty careproviders are more likely to encounter mass- and multiple-casualty-incidents and patients with catastrophic wounds. The epidemiology of wounding in OEF and OIF reveals a high incidence of penetrating trauma and blast-related mechanisms of injury.[11,12] Casualty evacuations tend to be longer in distance, duration, and complexity as compared to civilian settings. Such conditions combine to make CCC extremely challenging (Fig. 2).

As compared to civilian practice, TCCC providers are more likely to encounter penetrating trauma, blast-related mechanisms of injury, and mass- and multiple-casualty-incidents while facing more complex casualty evacuation scenarios.

In addition to the individual challenges of CCC, several systemic issues pose significant obstacles to the optimization of CCC in the modern battlespace. The most pressing of these issues is a lack of effective clinical data collection in the forward setting and the need for adaptation of clinical operating guidelines (COG) and scope of practice for out-of-hospital practitioners. Outcomes research in EMS is sparse in both the civilian sector and combat settings. Randomized, controlled, prospective trials are the exception rather than the rule.[13] Much of what is available comes in the form of case reports or series focusing on single aspects of out-of-hospital CCC or case series resulting from individual engagements.[14] A primary challenge facing military medical leaders is the development and implementation of an effective, sustainable, and physically hardy system for documenting and sharing the equivalent of what would be a routine patient care report (PCR). Until the advent of such a system, critical elements of out-of-hospital CCC will lag behind civil sector EMS. This lack of out-of-hospital clinical data presents a formidable obstacle to implementing a civilian sector EMS-style medical direction model with its component process improvement mechanisms, including field medical treatment record review.

Future steps include: (1) organizing and training the military's out-of-hospital enlisted CCC providers to a level approaching that of special operations advanced tactical practitioners; (2) optimally utilizing military emergency medicine-trained practitioners (including emergency physicians and specialty-trained physician assistants, and certified emergency nurses); and (3) developing true emergency medical direction capability. Reflecting the success of civil sector EMS and trauma systems, the future military EMS medical direction capability should encompass retrospective process improvement program management as well as online decision support to far-forward practitioners.[7] In the interim, it is incumbent on individual CCC providers to make the best effort possible to document and forward clinical data pertaining to the casualties they treat, the interventions they performed, and the resulting outcomes.

Tactical Combat Casualty Care (TCCC)

The inadequacy of applying a civilian trauma model to tactical situations has long been recognized.[15,16,17] The TCCC program was initiated by the Naval Special Warfare Command in 1993, and later continued by the US Special Operations Command (USSOCOM). This effort developed a set of tactically appropriate battlefield trauma care guidelines that provide CCC providers with trauma management strategies that combine good medicine with good small-unit tactics.[15] Tactical Combat Casualty Care guidelines recognize that trauma care in the tactical environment has three goals: (1) treat the casualty; (2) prevent additional casualties; and (3) complete the mission.

The first TCCC course was taught in 1996 in the Undersea Medical Officer course sponsored by the Navy Bureau of Medicine and Surgery (BUMED). Shortly thereafter, this training was mandated for all US Navy Sea-Air-Land (SEAL) naval special warfare corpsmen.[15] Since that time, TCCC has gradually gained acceptance in US and foreign military forces.[15,16,17,18,19,20,21,22,23] It has also found acceptance in the civilian law enforcement medical community.[24] Preliminary evidence from the current conflicts in Afghanistan and Iraq supports the contention that in the hands of clinically and tactically competent CCC providers, TCCC contributes to casualty survival.[25]

> Tactical Combat Casualty Care is divided into three phases: (1) care-under-fire, (2) tactical field care, and (3) tactical evacuation care.

Trauma care measures proposed in the original TCCC guidelines are outlined in Table 1. The overarching goal of the TCCC initiative is the combination of good tactics with good medicine. As the name implies, TCCC is practiced during combat missions. TCCC is divided into three phases: (1) care-under-fire, (2) tactical field care, and (3) tactical evacuation care. In care-under-fire, CCC providers and their units are presumed to be under effective hostile fire, and the care they are capable of providing is very limited. In the tactical field care phase, CCC providers and their patients are no longer under effective hostile fire, and more extensive care can be provided. In the tactical evacuation care phase, casualties are transported to a medical facility by an aircraft, ground vehicle, or boat, and there is an opportunity to provide a higher level of care.

Original Tactical Combat Casualty Care Treatment Measures
1. Early use of tourniquets to control clinically important extremity hemorrhage
2. Systemic antibiotic prophylaxis near point of injury
3. Tactically appropriate intravenous or intraosseous access and fluid resuscitation
4. Improved battlefield analgesia (intravenous or intramuscular opiates)
5. Nasopharyngeal airways as first-line airway devices
6. Surgical airways for maxillofacial trauma with an obstructed airway
7. Aggressive diagnosis and treatment of tension pneumothorax via needle decompression
8. Incorporation of input from CCC providers into TCCC guidelines
9. Employment of tactically and clinically-relevant scenarios into TCCC training

Table 1. *Original Tactical Combat Casualty Care treatment measures.*

Care-Under-Fire Issues

The first phase of the TCCC paradigm is composed of two verbs: care and fire. This implies the unpleasant realities that one's unit has come under attack by hostile personnel who have made the unit the target of effective fire by one or more lethal weapon systems, and, as a result, someone has been wounded. The essential initial action is to return effective fire toward the threat with the specific intent of neutralizing or otherwise preventing hostile personnel from continuing to place effective fire on the CCC provider or their unit. Until this is accomplished, the CCC provider will be unable to render effective medical care, and the careprovider, fellow warfighters, or existing casualties could be further wounded or killed. A summary of actions conducted during the care-under-fire phase includes: (1) returning effective fire toward the source of hostile engagement; (2) tactical movement of the casualty and careprovider to an area of cover and concealment; (3) and the rapid assessment for sources of massive extremity hemorrhage amenable to placement of a tourniquet, followed by rapid tourniquet placement if practicable. Once these tasks have been accomplished and the unit is no longer under effective hostile fire, this phase of TCCC is complete (Fig. 3).

> In care-under-fire situations, the CCC provider should return effective fire, move the casualty to a safe area, rapidly assess the casualty for sources of massive extremity hemorrhage, and apply a tourniquet if necessary.

The care-under-fire phase of TCCC is often difficult for careproviders transitioning from civilian healthcare backgrounds. It is imperative that all CCC providers develop and maintain, at a minimum, basic proficiency in fundamental soldier skills prior to tactical deployment. Basic tactical warfighting skills include four fundamental components: shooting, moving, communicating, and surviving. It is important to: (1) understand how small units (squads, platoons, and companies) operate in combat; (2) know how to employ cover and concealment when moving tactically (both in vehicles and while dismounted on foot); (3) possess basic firearm marksmanship culminating in true proficiency with one's primary weapon and familiarity with other weapons used by one's unit or organization; and (4) have a working knowledge of how to locate and use the unit's radio and other available communications systems. A CCC provider should not presume the aforementioned skills will be provided by one's gaining unit. Rather, one should actively seek training and mentoring in these essential tasks prior to and during deployment.

Figure 3. (Above) *After returning effective fire, casualties should be moved to an area of cover and concealment and assessed for massive extremity hemorrhage amenable to placement of a tourniquet. Image courtesy of Defense Imagery Management Operations Center (DIMOC).*

Figure 4. (Right) *Hemorrhage control is a priority in all phases of TCCC. Tourniquets or hemostatic dressings combined with direct pressure should be applied early, when indicated. Image courtesy of Defense Imagery Management Operations Center (DIMOC).*

Tactical Field Care

Hemorrhage Control and Tourniquet Use

Uncontrolled hemorrhage remains the largest single cause of combat deaths, accounting for over 80 percent of combat deaths.[6] Moreover, compressible hemorrhage remains a significant cause of preventable battlefield deaths.[5,6] As such, the control of hemorrhage remains a priority in all phases of TCCC and includes the employment of hasty (rapidly applied) tourniquets as the primary means of controlling significant extremity hemorrhage (Fig. 4). After the casualty is extracted from effective hostile fire, hemostatic dressings may be placed with direct pressure applied to extremity bleeding sites, distal to tourniquets. Similarly, hemostatic dressings and direct pressure are applied to sources of bleeding on the torso and other sites that are not amenable to tourniquet application.

Uncontrolled hemorrhage remains the largest single cause of combat deaths, accounting for over 80 percent of combat deaths.

Extremity wounds that require continued tourniquet use for hemostasis should have hasty (rapidly applied) tourniquets converted to definitive (deliberate) tourniquets. This is accomplished by removing overlying clothing and armor and applying definitive tourniquets immediately proximal (two to three inches above the wound) to the hemorrhage site (e.g., mangled or amputated extremity). If required, additional tourniquets may be placed (in sequence longitudinally) proximal to the source of bleeding to reinforce the hemostatic effect. In situations where hasty tourniquets were placed in a care-under-fire scenario, reassessment of the injured extremity can now be performed in the tactical field care phase. In a hemodynamically stable patient, a tourniquet can be removed if the extremity injury was not as severe as originally judged, or hemostasis is maintained with hemostatic dressings and direct pressure. Additional information on tourniquets can be found in the Extremity Injury chapter.

Hemostatic Agents

Operation Enduring Freedom and OIF have supported important research, development, and acquisition efforts focused on creating effective hemostatic agents for out-of-hospital setting use. The use of parenteral hemostatic agents, such as recombinant factor VIIa, has been met with controversy and conflicting clinical data, resulting in limited use.[26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41] Likewise, there is little definitive clinical data supporting the use of hemostatic dressings, despite their ubiquitous presence on the battlefield.[42,43,44,45,46,47] First-generation agents such as Zeolite (QuikClot®) and Chitosan-impregnated semi-rigid dressings (HemCon®) have given way to hemostatic-impregnated gauze (e.g., Kaolin Combat Gauze™, HemCon ChitoFlex™, CELOX Chitosan Gauze™). The current TCCC guidelines recommend Combat Gauze™ as the hemostatic agent of choice for compressible hemorrhage not amenable to tourniquet use.[10] These hemostatic agents may offer incremental benefits, particularly in cases of junctional hemorrhage (inguinal or axillary wounds) or in cavitary wound applications. At present, there is insufficient evidence to recommend specific products over others in out-of-hospital care. It should be emphasized that proper dressing and bandaging techniques and the early and appropriate use of tourniquets are the most critical elements of out-of-hospital hemorrhage control.

Vascular Access and Fluid Resuscitation

Casualties with controlled sources of hemorrhage who have a palpable radial pulse and a normal mental status do not require immediate vascular access and resuscitative fluids in the out-of-hospital phase of care (Fig. 5).[48] Vascular access should be obtained for casualties with uncontrolled hemorrhage or in cases of presumed significant head injury (e.g., altered mental status) and significant blood loss. While peripheral intravenous access remains the criterion standard, the emergence of intraosseous devices has provided a viable alternative.[49] Requiring minimal training to achieve and maintain proficiency, common intraosseous devices in current military use employ the sternal manubrium, tibial tuberosity, lateral humeral head, or iliac crest as access sites and permit administration of resuscitation fluids, blood products, and many pharmaceuticals (Fig. 6).[50,51,52,53]

> Casualties with controlled sources of hemorrhage who have a palpable radial pulse and a normal mental status do not require immediate vascular access and resuscitative fluids in the out-of-hospital phase of care.

The optimal type and volume of intravenous solution to employ in acute hemorrhagic shock in the out-of-hospital tactical setting is still a subject for debate. Described by Beecher as a result of combat surgical experience in World War II and resurfacing with the work of Bickell et al. in 1994, the concept of hypotensive resuscitation has regained traction in the military CCC community.[49,54,55] The evidence in support of specific volumes and types of intravenous resuscitation fluids for use in combat is limited. Existing data does support logistical arguments favoring a hypotensive resuscitation scheme including the use of colloids due to decreased carrying weight and space requirements.[56] Hetastarch 6% in lactated electrolyte solution and 7% hypertonic saline (HTS) have been studied as fluid resuscitation solutions.[48,57] These resuscitation solutions effectively restore intravascular volume, minimize inappropriate immune response and cellular injury, and improve overall survival in the absence of blood products.[57] Of note, colloids such as hydroxyethyl starch have been known to increase coagulopathy (in vitro) by impairing von Willebrand factor activity in plasma.[58] The only trauma clinical trial involving Hextend® to date uncovered

Figure 5. *Casualties with controlled sources of hemorrhage who have a palpable radial pulse and a normal mental status do not require immediate vascular access and resuscitative fluids in the out-of-hospital phase of care. Image courtesy of Defense Imagery Management Operations Center (DIMOC).*

Figure 6. *If immediate vascular access is needed and a standard intravenous line cannot be established, intraosseous access should be obtained. All resuscitative medications and blood products can be infused via an intraosseous needle.*

no clinical signs of coagulopathy in the Hextend®-resuscitated group as compared to the control group.[59]

As a practical matter, hypertonic saline solutions are not readily available commercially for use as intravascular volume replacement, whole blood and fresh frozen plasma are currently impractical in tactical settings, and hemoglobin-based oxygen carriers are still under development. As of this printing, the current TCCC recommendation for intravascular fluid resuscitation is the use of Hextend® (6% Hetastarch in Lactated Electrolyte Injection) in 500 milliliter aliquots, with a maximum administration of 1,000 milliliters.[10] Similarly, the recommended resuscitation endpoints for combat casualties are evolving. Reasonable endpoints include a palpable radial pulse or a systolic blood pressure of 90 mm Hg and improved mental status in non-head-injured patients.[49]

Acute Airway Obstruction and Ventilatory Support

Recent analyses of preventable deaths in OEF and OIF revealed 10 to 15 percent of casualties were deemed to have acute airway obstruction or ventilatory failure as a proximate cause of death.[6,60,61] To further underscore the need for out-of-hospital phase early airway support, a subanalysis of the Registry of Emergency Airways at Combat Hospitals (REACH) study by Adams et al. reported that 76 of 1,622 subjects (5 percent) arrived at a Combat Support Hospital (CSH) without a definitive airway, despite needing one.[62]

> Ten to 15 percent of preventable deaths in OEF and OIF were attributed to acute airway obstruction or ventilatory failure.[60,61]

The CCC provider must be able to provide basic and advanced airway support and control. This includes use of basic airway adjuncts (oral and nasopharyngeal airways), providing bag-valve-mask ventilatory support, establishing definitive airways (endotracheal intubation and cricothyroidotomy), and using a portable mechanical ventilator. While rapid sequence direct laryngoscopic orotracheal intubation remains the criterion standard for advanced airway management in the civil sector, its efficacy and continued role in the out-of-hospital setting remains the subject of debate.[63,64,65,66] Furthermore, this intervention does not translate well into the tactical environment, unless performed by practitioners who are proficient in its execution.[9,62] According to TCCC guidelines, surgical cricothyroidotomy (provided careproviders are trained in its performance) is the preferred method for establishing a definitive airway during tactical field care or the tactical evacuation phase.[1,9,10,17] This recommendation assumes careproviders in the field lack the necessary equipment, pharmaceutical agents, or training to perform rapid-sequence orotracheal intubation.

Alternative methods of securing a definitive airway in the tactical environment include standard laryngoscopic orotracheal intubation, blind insertion airway devices, such as laryngeal tube devices, or esophageal gastric tube airways. Laryngeal-mask airways (LMA) are considered a temporizing airway measure as opposed to a definitive airway. While they are among the easiest-to-use, they are limited by their inability to be firmly secured in place and provide definitive airway protection. Lastly, the recent advent of video-based laryngoscopic devices (such as Glidescope® and RES-Q-SCOPE®) may offer a viable option for orotracheal intubation in field and transport settings; however, data confirming efficacy in this setting is lacking.[67,68,69]

Ensuring combat casualties have a secure and patent airway is strongly recommended during the tactical field care phase prior to tactical evacuation. In circumstances where this is impossible or impractical, the practitioner's goal will shift toward attempting to prevent airway compromise en route, as the environment in most evacuation conveyances is suboptimal at best for advanced airway placement. In the event that unanticipated airway compromise occurs during evacuation, the practitioner must rapidly assess the likely cause and attempt to mitigate it. Simple suctioning and jaw-thrust maneuvers may suffice. If these initial interventions fail, the practitioner may be forced to perform an advanced airway maneuver. Under such circumstances, the decision whether to perform surgical cricothyroidotomy or to employ alternative methods of securing an airway will have to be made, taking into consideration the patient's unique anatomy, conditions in the vehicle (vibration, kinetics, visibility, maneuver room), available airway supplies, and skill of the CCC provider.

Tension Pneumothorax

Traumatic pneumothorax is a potentially life-threatening condition and may rapidly progress to tension pneumothorax, an immediate life-threat. Likewise, an accumulating hemothorax or hemopneumothorax may cause similar cardiovascular collapse due to both ongoing hemorrhage, as well as the introduction of tension physiology.

Tension pneumothorax, hemodynamically significant hemothorax, or tension hemopneumothorax should be suspected in the setting of blunt or penetrating thoracic trauma when a combination of the following

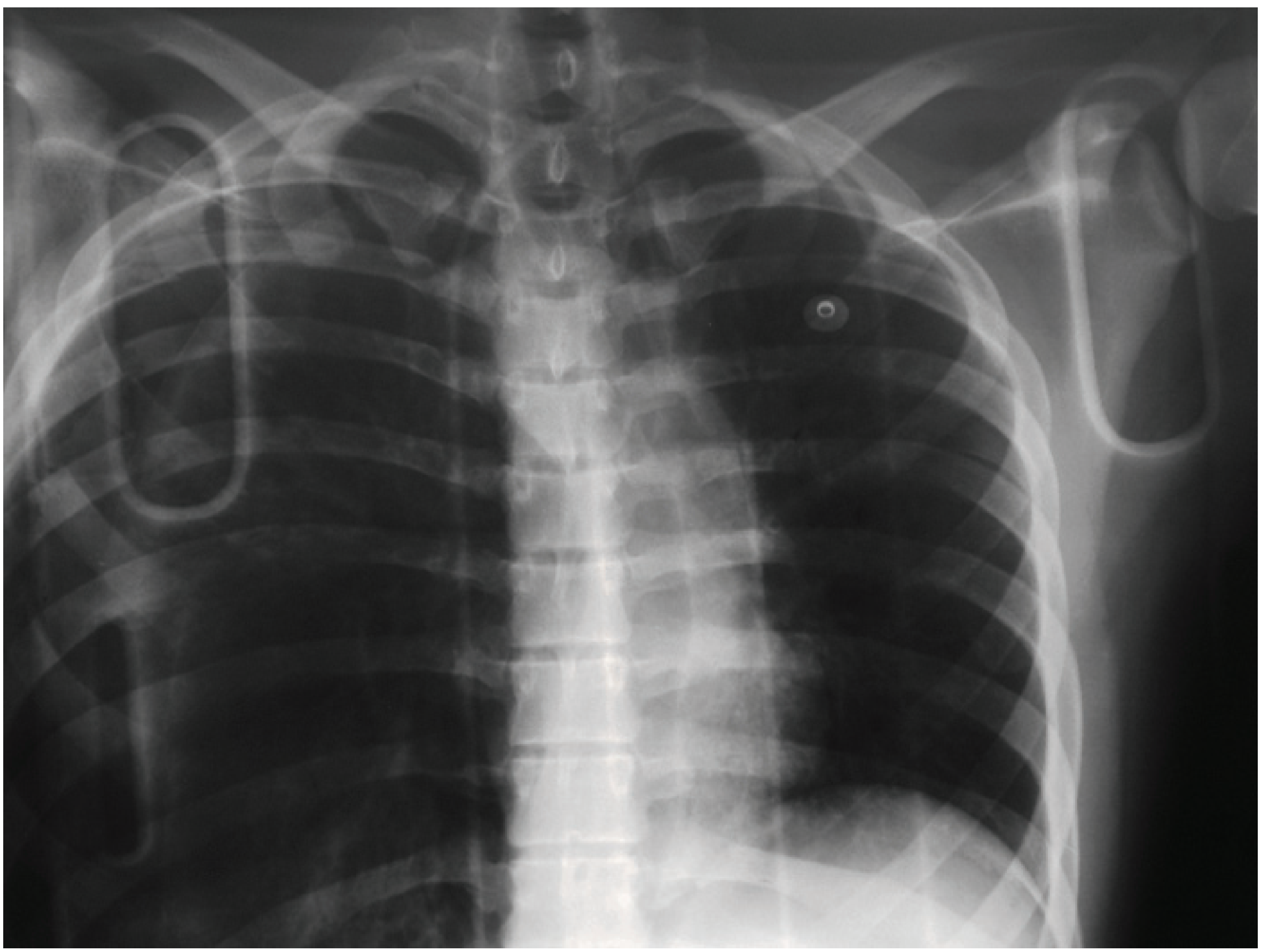


Figure 7. *Immediate needle thoracentesis should be performed in cases of suspected tension pneumothorax.*

clinical findings are present: progressive respiratory distress, hypotension, contralateral tracheal deviation, hyperresonance or dullness on percussion of the affected hemithorax, asymmetric chest wall rise with inhalation, or ipsilateral or bilateral decreased breath sounds upon auscultation. Under such conditions a needle thoracentesis should be performed. A 14-gauge intravenous catheter with a minimum length of eight centimeters (3.25 inch needle/catheter unit) is placed in the second intercostal space along the midclavicular line.[10,70,71] The recently revised recommendation to use a longer needle is based on data indicating a larger chest wall thickness in military personnel.[71] Tube thoracostomy should follow needle thoracentesis at the earliest possible juncture. Chest tube insertion in the setting of a pneumothorax is strongly recommended in advance of tactical evacuation, particularly if casualties will be transported by air. If this is not practicable, placement of a three-way stopcock for serial decompression or repeated needle thoracentesis may be required. The casualty should be closely monitored for recurrence of tension pneumothorax (Fig. 7).

Spinal Injury Precautions

In the current conflicts in Afghanistan and Iraq, spinal trauma is an increasing source of morbidity often leading to spinal cord injury and paralysis.[72] Cervical, thoracic, and lumbar spinal injuries (along with multiple spinal level injuries) are encountered in combat casualties injured by gunfire, explosions, motor vehicle accidents, and falls.[73,74,75,76]

Although recently challenged in cases of penetrating spinal trauma, spinal immobilization is a fundamental tenet of out-of-hospital EMS practice in the civil sector.[77] The employment, methods, and point of initiation of spinal immobilization in combat settings differ by necessity from civil sector practice. Factors influencing this phenomenon include tactical considerations, the effect of individual body armor on both spinal immobilization and alignment, and the logistical challenges associated with the movement of a properly immobilized patient through the tactical evacuation chain.

> By necessity, the employment, methods, and point of initiation of spinal immobilization in combat settings differ from civil sector practice.

There is insufficient literature to provide definitive guidelines on spinal immobilization in tactical settings.[78] First responders will need to use their best judgment in such settings. When a CCC provider suspects spinal trauma, tactically sound attempts at maintaining the casualty's spinal column in as near-neutral a position as possible should be attempted during care-under-fire and initial extrication. Individual body armor, though in itself a potential source of spinal misalignment, should remain on the casualty for as long as there continues to be a realistic threat of further engagement by hostile ordnance (Fig. 8). When tactical conditions allow, individual body armor should be removed or loosened to facilitate further casualty examination. If suspicion for spinal injury persists after secondary survey, and tactical conditions permit, individual body armor should be removed and spinal immobilization measures instituted. Spinal injury precautions should then be maintained throughout tactical evacuation (Fig. 9).

> Spinal immobilization techniques used in a combat setting mirror those found in the civilian sector.

Traumatic Brain Injury

Blunt and penetrating head injuries are common occurrences in OEF and OIF, despite the advent of Kevlar-based helmets.[6] The continued use of roadside bombs by enemy combatants has accelerated efforts

Figure 8. *An injured US Army soldier aboard a UH-60 Black Hawk MEDEVAC helicopter as he is airlifted to a Level III facility. Individual body armor should remain on the casualty for as long as there continues to be a realistic threat of further engagement by hostile ordnance. Image courtesy of Defense Imagery Management Operations Center (DIMOC).*

Figure 9. *Spinal immobilization applied during a training drill. Image courtesy of Defense Imagery Management Operations Center (DIMOC).*

to improve both diagnostic and therapeutic approaches to traumatic brain injury. Civilian research studies have established that patients suffering severe head injuries complicated by episodes of transient hypoxia or hypotension in the prehospital phase of care have worse outcomes.[79] As such, out-of-hospital careproviders should attempt to prevent episodes of hypoxemia and hypotension in patients with traumatic brain injuries. Casualties with head injuries who manifest signs of hemorrhagic shock should undergo interventions directed towards hemorrhage control, optimization of airway and ventilatory status, and restoration of adequate tissue perfusion. The goal of airway and ventilatory support in the tactical setting is to maintain adequate tissue oxygenation and normal ventilation. Patients should have their partial pressure of oxygen in arterial blood (PaO_2) maintained at or above 60 mm Hg (pulse oximeter reading greater than 90 percent oxygen saturation) and partial pressure of carbon dioxide (PCO_2) values in the normal range of 35 to 40 mm Hg.[79] While endpoints of fluid resuscitation in the tactical setting include a palpable radial pulse or improved mental status in non-head-injured patients, alternative strategies may be indicated in patients with suspected traumatic brain injury. More aggressive fluid resuscitation may be required to minimize secondary brain injury from hypotension (defined as systolic blood pressure less than 90 mm Hg). The ability to meet these parameters in a tactical field care setting is complicated by numerous factors.

In patients with suspected head injury, more aggressive fluid resuscitation strategies may be necessary to minimize secondary brain injury from cerebral hypoperfusion resulting from systemic hypotension.

Patients with blunt head injuries are at risk for coexisting cervical spine injury.[80,81,82] Hence, spinal immobilization or at least maintenance of neutral spinal alignment is recommended at the earliest possible juncture during the tactical field care phase. Similar to casualties with other causes for potential closed-space gas collection, patients with suspected intracranial injury should be transported with the minimal possible increase in altitude and should be positioned in a neutral supine position.[83] Early post-traumatic seizures have been observed in 5 to 30 percent of severe head injury patients and may exacerbate secondary brain injury.[84,85] Seizures occurring in the tactical setting may be controlled initially with benzodiazepines administered via intramuscular, intravenous, intraosseous, or rectal routes. Airway control and breathing support in the setting of head trauma and seizures are important because the administration of benzodiazepines may hasten or exacerbate hypotension and ventilatory insufficiency.

A final consideration in the tactical care of head injury patients is the potential need for neurosurgical intervention and the availability of such services within range of evacuation assets. The determination of whether to seek the nearest resuscitative surgical care versus overflight to more comprehensive medical treatment facilities is a complex decision. These decisions can be made by communicating with Level III careproviders, ideally prior to evacuation of the combat casualty.

Hypothermia Prevention and Management

Hypothermia is recognized as an independent factor contributing to increased morbidity and mortality in trauma patients.[86] In the combat casualty, hypothermia may occur due to prolonged prehospital time, cold fluid administration, environmental factors, and trauma-related bleeding and hypoperfusion. Arthurs et al. found that 18 percent of casualties presenting to a CSH in OIF were hypothermic (temperature less than 36˚C).[87] Keeping a patient warm, especially early in tactical field care, will minimize subsequent hypothermia and resultant cold coagulopathy. This may be accomplished using passive external means, such as blankets, vehicle heating systems, hats and hoods to minimize heat loss from the head and scalp, and by ensuring that wet clothing or dressings are replaced. The recent fielding of the Hypothermia Prevention and Management Kit (HPMK®), which is composed of a disposable weather-resistant bag, insulating liner, chemical heat packet, and a heat-radiant cap, has capitalized on several effective field-expedient

Figure 10. *A US casualty being loaded onto a UH-60Q Black Hawk helicopter in Afghanistan. Note casualty is covered in a solar blanket. Image courtesy of Defense Imagery Management Operations Center (DIMOC).*

treatments developed by tactical practitioners (Fig. 10). Many alternative hypothermia prevention devices exist (e.g.,Thermal Angel®, ChillBuster®, Blizzard Survival Blanket).

The CCC provider should be cognizant of the relative temperatures of intravenous fluids being administered to casualties. Ideally, intravenous fluids are delivered at body temperature. Infusing cold fluids will hasten hypothermia and initiate cold coagulopathy. Potential tactical countermeasures include storage of small volume intravenous fluids on the body (in the axilla against the torso), field-expedient insulation of intravenous tubing using rolled paper or cloth, and placement of the intravenous infusion set along with the casualty in a sleeping bag or similar cover.

Infection Prophylaxis

It is a widely held belief in military medical circles that combat wounds are more likely to become infected than corresponding wounds occurring in the civilian sector setting. Gerhardt et al. presented data that both lent credence to this notion and also provided evidence in support of copious wound irrigation and systemic antibiotic prophylaxis of combat wounds in a population of subjects not requiring surgical intervention.[88] In this study, infections developed within 48 hours in 7 percent of subjects receiving systemic antibiotic prophylaxis versus 40 percent without antibiotic prophylaxis. Infections developed within 48 hours in 4.5 percent of cases undergoing wound irrigation versus 55 percent of cases that did not undergo irrigation. Further analysis demonstrated that the lowest infection rates were associated with the combination of systemic antibiotic prophylaxis and irrigation. The high frequency of complex combat wounds, delays in evacuation to definitive care, and the logistical difficulty associated with irrigation at the point of injury support the current TCCC guideline encouraging early systemic antibiotic prophylaxis after wounding through the use of combat pill packs on the battlefield.[10]

> Evidence supports the use of systemic antibiotic prophylaxis and copious wound irrigation in the management of combat wounds.

Tactical Combat Casualty Care recommendations for systemic antibiotic prophylaxis include moxifloxacin (400 milligrams by mouth once daily) for patients who are able to tolerate oral administration, or intravenous cefotetan (2 grams every 12 hours) or ertapenam (1 gram intravenously or intramuscularly once daily).[10] Of note, the author (RG) has utilized oral levofloxacin or intramuscular/intravenous ceftriaxone to good effect. An additional factor in favor of these latter antibiotics is the widespread availability of these agents throughout the current battlespace.

Pain Management

Despite decades of dogma to the contrary, numerous studies have demonstrated that the judicious use of analgesic agents does not significantly alter the physical examination or impede medical diagnosis.[89] The timely and adequate relief of pain is both humane and often the only effective treatment that may be offered to a casualty.[83] In addition, recent evidence supports the contention that the failure to address acute pain in the setting of combat wounds may increase the incidence of both post-traumatic stress disorder and chronic regional pain syndromes.[90,91]

> Use of analgesics does not significantly alter physical examination or medical diagnosis.

In the setting of mild, particularly musculoskeletal injuries, a nonsteroidal antiinflammatory drug (NSAID) may be administered. For more severe wounds, or if a NSAID fails to provide adequate relief, opioid analgesics (e.g., morphine sulfate) provide potent acute analgesia. Intramuscular use of opiates is discouraged, due to unpredictability of absorption and bioavailability. Oral or intravenous preparations are recommended. As of this writing, oral transmucosal fentanyl citrate (OTFC) is emerging as a potential solution for tactical analgesia (800 micrograms transbuccally). Although this is an off-label use of this medication and the Food and Drug Administration (FDA) has issued a black box warning that states that oral transmucosal fentanyl citrate should not be used except for breakthrough pain in opioid-tolerant patients, this medication has been used safely in combat.[92] Current TCCC recommendations for combat pill packs include meloxicam (15 milligrams by mouth once daily). Meloxicam was selected due to its lack of a sulfa moiety, which could prove hazardous in cases of sulfa-allergic casualties.[10]

Air Medical Evacuation Considerations

Air medical transport can adversely affect medical conditions characterized by gas trapped in a fixed space such as untreated pneumothorax. Lower ambient atmospheric pressures at altitude cause intrapleural gas to expand with a resultant increased compression of the heart and contralateral lung. The practical effect of Boyle's law ($P_1V_1=P_2V_2$; P denotes the pressure of the system, and V denotes the volume of the gas) on a casualty with an untreated simple pneumothorax undergoing air evacuation via an unpressurized compartment is development of a tension pneumothorax after ascent to altitude. The same may be said for other trapped-gas clinical conditions. As a result, it is recommended that patients suspected or known to have a pneumothorax receive decompression of the affected anatomical space prior to transport.[83] If decompression is not performed, evacuation should be conducted via routes that minimize elevation within the confines of the tactical situation. Although little scientific evidence exists for such cases, avoiding ascent to altitudes in excess of 5,000 feet above mean sea level has been recommended.[93] In cases where a unit is operating in alpine terrain (routinely above 5,000 feet mean sea level), the authors' recommend minimizing further ascent, to the extent possible. Air medical transport-related barometric complications also include pneumocephalus, pneumoperitoneum, and overexpansion of endotracheal and Foley catheter tube cuffs filled with air.[83] Endotracheal tube and Foley catheter cuffs should be filled with crystalloid solutions or sterile water prior to evacuation, mitigating the risk of cuff overexpansion. Occlusive dressings covering thoracic puncture wounds should be checked periodically while en route and should be vented as clinically indicated.

Tactical Evacuation Care

Once casualties arrive at a company combat casualty collection point or equivalent element, evacuation becomes the responsibility of the gaining medical unit. As such, each Battalion Aid Station is equipped with an ambulance squad and charged with transport of casualties from casualty collection point to Battalion Aid Station. Likewise, each Brigade Support Medical Company (BSMC) possesses ambulance platoons to transport patients from the Battalion Aid Station to the Brigade Support Medical Company and to coordinate ambulance exchange points in settings where distances or terrain separating medical treatment facilities are prohibitive. In addition to these unit-level assets, combat divisions possess Medical Companies (Air Ambulance), more commonly known as MEDEVAC units. These units are often allocated to subordinate medical units, or staged at Level III facilities such as CSHs.

There will be circumstances when the evacuation capabilities of maneuver units are temporarily overwhelmed. It is under these circumstances that nonstandard vehicles may be employed for casualty evacuation. While often necessary in mass-casualty-incidents, this form of transportation should be considered a last resort. This is because of the relative difficulty involved in adequately securing patients for transport and the probable lack of en-route-care resulting from the absence of medics assigned to the casualty evacuation (CASEVAC) vehicles.

After initial triage and stabilization, casualties in the tactical setting are categorized for evacuation.[83] Traditionally, the primary objectives of air medical evacuation have been speed and access. While quantitative data are lacking, the transport time interval between point of injury to damage control resuscitation and damage control surgery is perceived as critical to the survival of combat casualties in OEF and OIF. Designated MEDEVAC precedence categories (urgent, urgent surgical, priority, routine, and convenience) are used to determine evacuation priorities and should not be confused with US/NATO mass casualty triage categories (immediate, delayed, minimal, expectant, and urgent surgical) (Fig. 11).

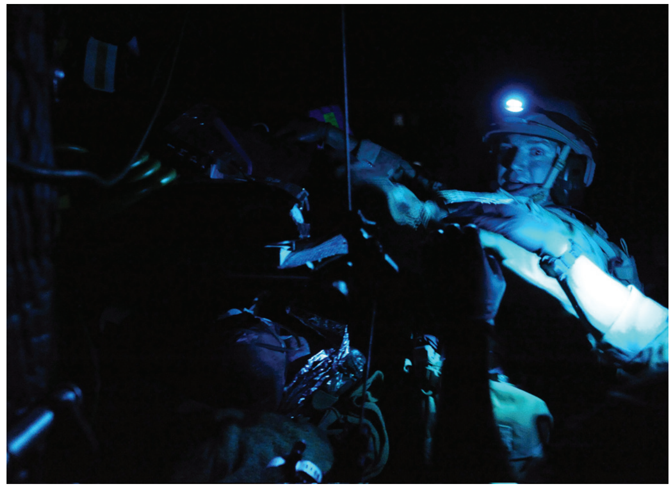


Figure 11. *A severely wounded service member aboard an HC-130P Hercules aircraft flying over Afghanistan en route to a CSH. Image courtesy of Defense Imagery Management Operations Center (DIMOC).*

> The transport time interval between point of injury to damage control resuscitation and damage control surgery is critical to the survival of combat casualties in OEF and OIF.

The urgent evacuation category is reserved primarily for casualties requiring immediate care who should be evacuated within a maximum time interval of one hour. An urgent surgical subcategory exists for casualties deemed to be at the greatest severity who require rapid evacuation for lifesaving surgical interventions to prevent death. Under current US and Coalition doctrine, urgent patients receive MEDEVAC if weather and tactical conditions allow. Priority evacuation is conducted mainly for delayed category casualties requiring transport to higher level care within four hours in order to avoid deterioration to an urgent condition or to avoid undue pain or disability. This category usually is transported via ground assets, although air transport may be used under some conditions. Routine evacuation is reserved for casualties triaged as minimally injured, and generally is performed by standard ground or waterborne assets within 24 hours of the initial event. Convenience denotes cases where medical evacuation is performed for convenience rather than necessity. It is worth noting that a recent requirement placed by the Office of the Secretary of Defense now mandates a one-hour evacuation for urgent casualties.

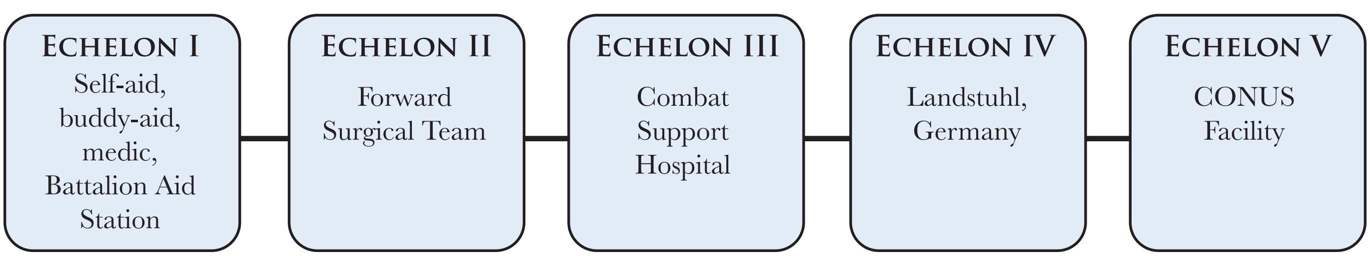


Figure 12. *Evacuation chain for combat casualties.*

Another challenge to the evacuation system is the ability to deliver effective, advanced en-route-care (Fig. 12). Traditionally, MEDEVAC platforms have been staffed with combat medics or their sister-service counterparts. Training and experience levels vary widely, as does the capability to provide or continue advanced lifesaving interventions such as ventilatory, circulatory, or pharmacological support.[94,95] Given the limited scope of practice of Army flight medics who staff MEDEVAC aircraft, the need to augment the MEDEVAC crew with an advanced practice medic or credentialed provider should be anticipated if critically injured patients will be transported.[94,95]

Figure 13. *A US casualty with a neck injury is loaded onto a UH-60 Black Hawk MEDEVAC helicopter at a landing zone in Camp Victory, Iraq. Image courtesy of Defense Imagery Management Operations Center (DIMOC).*

The US military refers collectively to the effects of the operational milieu as mission, equipment, terrain and weather, time, troops (both US and enemy combatants), and civilians (METT-TC) on the battlefield.[96] All of these factors possess the potential to impact, either positively or negatively, an evacuation plan. Combat casualty careproviders must be aware of these issues as they affect both tactical and medical operations. Operational areas may be broad and deep, resulting in significantly greater distances required for evacuation. These conditions compound the standard risks inherent in tactical evacuation and en-route-care. As a result, evacuation planning and coordination among first responders, destination facilities, evacuation assets, and maneuver elements become critical for mission success and casualty survival.

Important time-distance considerations in casualty evacuation and en-route-care include:

1. Location, number, and type of elements supported
2. Their internal (organic) medical support and evacuation assets
3. Location of echelon II and III combat health support units in your respective Area of Responsibility (AOR)
4. Terrain features affecting potential evacuation routes
5. Analysis of adversary locations, capabilities and limitations, and prior conduct toward noncombatant medical units
6. US or Coalition maneuver and support elements available to escort or otherwise assist the evacuation mission
7. Friendly evacuation assets available to you, including dedicated medical evacuation vehicles and aircraft, nonstandard vehicles, potential crew members, and nonmedical attendants
8. Your source of launch authority

The METT-TC information forthcoming from the requesting unit is most readily obtained by receipt of a standard MEDEVAC request, usually composed in a nine-line format. An example of a standard MEDEVAC request appears in Table 2.

Nato Nine-Line Medevac Request
1. Location of landing zone (LZ) for casualty collection (eight digit MGRS grid coordinates) 2. Radiofrequency, call sign, and suffix of requesting element 3. Number of patients by precedence: A - Urgent B - Urgent surgical C - Priority D - Routine E - Convenience 4. Special equipment required: A - None B - Hoist C - Extrication equipment D - Ventilator E - Other (specify) 5. Number of casualties by type A - Litter B - Ambulatory C - Escort 6. Security at LZ / pick-up site N - No enemy troops in area P - Possible enemy troops – approach with caution E - Enemy troops in area X - Enemy troops in area – armed escort required 7. Method of marking LZ* / pick-up site A - Panels (VS-17 or similar) B - Pyrotechnic C - Smoke D - None E - Other (specify) *Methods may be listed by local tactical standard operating procedures 8. Casualty nationality and status A - Coalition military B - Coalition civilian C - Non-Coalition forces D - Non-Coalition civilian E - Opposing forces detainee F - Child 9. Pick-up zone terrain obstacles

Table 2. *NATO nine-line MEDEVAC request.*

Air medical evacuation is the primary method for urgent and urgent surgical casualties, and may be appropriate for priority casualties (Fig. 13). The decision to employ MEDEVAC support is complicated by many variables and must take into account the vulnerability of rotary wing aircraft to virtually any modern weapons system.[83] This risk is amplified in urban terrain or mountains where flight paths and landing zones often intersect closely with terrain features of similar or greater elevation, providing optimal battle positions to engage the aircraft with hostile fire. A sobering thought to be considered by anyone requesting MEDEVAC is the possibility that both the casualty and the MEDEVAC crew might perish as the result of hostile fire or marginal flight conditions.[83] As such, these resources should be used carefully, and the decision to employ MEDEVAC should be made with input by competent clinical and tactical operators with a minimum of emotion. Appropriate indications for air medical evacuation are outlined in Table 3.

Indications for Air Medical Evacuation
1. Casualties meeting criteria for urgent evacuation (loss of life, limb, or eyesight within two hours)
2. Casualties meeting priority evacuation criteria, but for whom other means of evacuation will cause deterioration
3. Circumstances in which the organic (internal) medical capabilities of the supported unit have been rendered ineffective (e.g., mass-casualty-incident, medical element neutralized by hostile action)
4. Risk of loss of evacuation aircraft and air crew is considered manageable by launch authority

Table 3. *Indications for air medical evacuation.*

Health Services Support (HSS): Echelons, Levels, and Roles of Care

Nearly two decades after the end of the Cold War the US and its Allies are facing new and emerging threats. Military operations are often conducted in an expeditionary fashion employing minimal permanent footprints in host or target nations and often involve nonpermissive or forced initial entry operations. The physical environment for most current conflicts has shifted from remote to urban. Emphasis has also shifted from major theater wars to full-spectrum operations, including simultaneous combat and stability and peacekeeping operations. Retired Marine Corps General Charles Krulak summarized this concept as "the Three Block War." [97,98] New paradigms have been developed for defining, identifying, and mitigating threats to the US and its Allies.[98]

Traditionally, the US Army divided CCC and evacuation into five levels corresponding to the command and control echelons of the battlespace (Fig. 12). Echelons I to III compose the combat zone, while echelon IV consists of the communications zone, and echelon V is the zone of the interior, or US Homeland. The medical care delivered at each echelon of the battlefield is referred to as respective levels of care. Thus, at echelon I (unit level), one would encounter Level I medical care, comprising self- and buddy-aid, initial treatment by a combat lifesaver, and emergency medical treatment by a healthcare specialist (known more commonly as a combat medic). In most cases, Level I care also encompasses company casualty collection points and Battalion Aid Station care. Doctrinally, the evacuation of casualties from the Battlefield Aid Stations would progress to echelon II (division level), with its corresponding Level II care, which focuses primarily at the Brigade Support Medical Company. Level II care includes advanced trauma management by physicians and physician assistants. Level II facilities are equipped with limited plain radiography and laboratory services and, in some instances, may be supplied with blood products for emergency transfusion. In addition, the Brigade Support Medical Company is also the primary site of attachment for Forward Surgical Teams (FSTs), which are capable of conducting forward resuscitative surgical interventions aimed primarily at hemostasis of non-compressible hemorrhage, such as intraabdominal or intrathoracic wounds.

Traditionally, the US Army divided CCC and evacuation into five levels corresponding to the command and control echelons of the battlespace. The medical care delivered at each echelon of the battlefield is referred to as respective levels of care.

Figure 14. *Medical care at a Forward Resuscitative Surgical System. Image courtesy of Harold Bohman, MD, CAPT, MC, US Navy.*

While the traditional system describes Army CCC doctrine, the Navy and Marine Corps possess additional out-of-hospital units. These include Forward Surgical Companies, Forward Resuscitative Surgical Systems (FRSS), and Shock Trauma Platoons (STP) (Fig. 14). The Forward Resuscitative Surgical Systems share some similarities with the Army Forward Surgical Teams but have several notable differences, including self-sustainability and the assignment of an emergency physician to the unit. The Shock Trauma Platoons consist of two emergency physicians, physician assistants, an emergency nurse, and several medical corpsmen (the Navy equivalent of the combat medic). Both the Forward Resuscitative Surgical Systems and Shock Trauma Platoons are capable of augmenting a Battalion Aid Station or Brigade Support Medical Company in mass-casualty circumstances, such as might be expected during an amphibious assault or vertical envelopment (helicopter or Vertical Take-Off and Landing [VTOL]) entry operation.[99] The Forward Resuscitative Surgical Systems and Shock Trauma Platoons may also be combined into a hybrid entity known as a Surgical Shock Trauma Platoon (SSTP), representing perhaps the most robust forward medical capability within the Department of Defense. Lastly, the Air Force maintains Mobile Field Surgical Teams (MFST) as part of its modular Expeditionary Medical System (EMEDS), possessing resuscitative surgical capability, emergency care, and a preventive medicine cell (Fig. 15).[100]

If required, evacuation continues to echelon III (corps level), where the Level III Army CSHs, Navy Expeditionary Medical Facilities (EMF), and Air Force Theater Hospitals (AFTH) conduct both resuscitative and definitive surgery to save life, limb, and eyesight. If more complex surgical intervention or prolonged convalescence is required, casualties may be evacuated to echelon IV (communications zone level), where regional medical centers provide Level IV tertiary care and convalescence for up to two weeks. These facilities are currently located in Germany and Hawaii. The most severely injured, requiring extensive rehabilitation and convalescent care, are evacuated to echelon V (zone of interior or continental US). Here they receive Level V care at Army, Navy, and Air Force medical centers, and in the event of medical discharge, at Department of Veterans Affairs medical facilities.

Army Echelon I/II CHS	USN/USMC Echelon I/II CHS	USAF Echelon I/II CHS
✓Front-loaded for unit level basic life support care	✓BALANCED and PROGRESSIVE levels of care	✓Minimal Echelon I/II CHS (EXCEPT AFSOC)
✓Often, this care CANNOT be rendered due to METT-TC	✓Advanced life support / emergency careproviders far-forward	✓Advanced life support/ emergency careproviders forward deployable
✓No true advanced life support care until FST/CSH	✓Self-sustaining resuscitative surgery far-forward	✓Self-sustaining resuscitative surgery far-forward
✓EVAC care MAY be a step-down in scope of practice	✓Advanced life support "CASEVAC" support available	✓Advanced life support "CASEVAC" support available
✓LEGACY "medic-to-surgeon" mentality	✓WEAKNESS: No dedicated tactical MEDEVAC	✓WEAKNESS: Generally are not deployed forward of facilities capable of resuscitative surgery and secure airstrip
ARMY is exclusively responsible for tactical MEDEVAC in joint operations models	USN/USMC model likely represents the optimal current model for forward CHS, but is difficult to sustain in terms of personnel	USAF has MOST ADVANCED forward CHS capability—an "underutilized" resource?

Figure 15. *Attributes of Echelon I/II combat health support (CHS) units in branches of the US military.*

This complex description of echelons of the battlefield and levels of health care has recently undergone further revision in order to meet North Atlantic Treaty Organization (NATO) standards.[101] Utilizing Roles of Care, the NATO system simplifies the levels of care based upon the availability and sophistication of surgical intervention. Under the NATO system, Role I medical treatment encompasses out-of-hospital and presurgical care analogous to Level I and Level II (absent forward surgical attachments). Role II also encompasses out-of-hospital care but incorporates forward resuscitative surgical capability and advanced resuscitative techniques, thus requiring the presence of a Forward Surgical Team, Forward Resuscitative Surgical System, or Mobile Field Surgical Team. Role III represents theater hospitalization, correlating directly to Level III. Finally, in the NATO system, Levels IV and V are combined into Role IV, representing continued surgical, recuperative, and rehabilitative care outside of the combat zone.

Mass-Casualty-Incident Management

US and NATO Military Mass-Casualty Triage Systems

In US military parlance, a mass-casualty-incident is defined as a casualty-producing event that overwhelms the existing medical capacity of the receiving facility or of the unit providing medical support in the out-

Figure 16. *Multiple-casualty-incident at a Level III facility.*

Figure 17. *Use of portable ultrasonography at a Level III facility.*

of-hospital setting. After initial collection, sorties of casualties who arrive in numbers sufficient to initially overwhelm the treatment and evacuation resources are triaged for priority of treatment (Fig. 16). The US military mass-casualty triage process comprises immediate, delayed, minimal, expectant, and urgent surgical categories. This is similar to the NATO triage system, which is partly based upon Medical Emergency Triage Tags (METTAG) methodology. Unlike METTAG, the US/NATO system adds a fifth urgent surgical category, which has been used to describe surgical patients who need an operation but can wait a few hours. It is important to note that urgent surgical patients who receive the appropriate initial categorization (e.g., urgent surgical) and intervention may be sufficiently stabilized and retriaged to a lower subsequent category (e.g., delayed). This US/NATO triage categorization should not be confused with MEDEVAC precedence categories (urgent, urgent surgical, priority, routine, and convenience) that are used to determine evacuation priorities.[102]

Similar to the NATO triage system, the US military mass-casualty triage process comprises immediate, delayed, minimal, expectant, and urgent surgical categories.

Beekley et al. recorded a series of "lessons learned" in mass-casualty triage conducted at surgical facilities in Iraq, which may have some application in the out-of-hospital setting.[103] They included the observation that the requirement to perform triage in close proximity to the medical treatment facility can complicate the process. Likewise, the type of evacuation platform upon which casualties arrive may adversely affect the triage process. While Beekley et al. may have been referring to variation in numbers of casualties-per-sortie, what is of equal import is that the arrival of large sorties of casualties in high-capacity conveyances (such as flatbed trucks and buses) generally equates to a relative lack of en-route-care and minimal casualty triage. Beekley et al. also emphasized the importance of retriaging at progressive treatment sites as well as after time elapses, particularly in situations where significant delays in access to surgical intervention may occur. Lastly, Beekley et al.'s observations regarding the utility of focused abdominal sonography in trauma (FAST) as a triage tool resonated with similar anecdotal experiences by forward practitioners. While ultrasound use near point of injury is logistically and tactically undesirable, it has been successfully employed at Battalion Aid Stations, casualty collection points, and MEDEVAC landing zones, particularly in cases of prolonged delays in evacuation. In addition to traditional FAST applications, McNeil et al.[104] employed ultrasound for assessment of long-bone fractures. Potential additional uses include ocular assessment for intracranial pressure elevation, thoracic ultrasound for pneumothorax, and vascular assessments for diagnosis and access (Fig. 17).

The authors' practical experience with current NATO triage methodology has been satisfactory, but its effectiveness is dependent upon the practitioner being facile with the common types of injuries and associated respective triage categories. Anecdotal reports from the field indicate that many CCC providers, and in particular those with less clinical experience, tend to overtriage patients. Alternatively, overtriage may arise from the desire to not underestimate a casualty's injuries or from personal motivation to secure expeditious evacuation for patients who are acquaintances or close personal friends. While laudable, this practice should be avoided as it poses the potential to deplete limited MEDEVAC resources and may place MEDEVAC crews and aircraft in excessive danger for what might amount to relatively minor and otherwise survivable injuries.

Alternative Mass-Casualty Triage Systems

Alternatives to the US/ NATO and METTAG systems include but are not limited to the Simple Triage And Rapid Treatment (START®) triage system, the International Committee for the Red Cross (ICRC) method, and the Sort, Assess, Lifesaving Interventions, Triage/Treat/Transport (SALT) system. The START® methodology incorporates a very brief assessment (spontaneous respiration, presence of peripheral pulses, level of consciousness) and simple interventions (noninvasive airway maneuvers, tourniquets) to triage casualties into one of five color-coded categories: immediate (red), delayed (yellow), minimal (green), expectant/salvageable (blue), and expectant/unsalvageable (black). The blue category represents casualties who might be saved, but who require such intense resource allocation that they would likely cause the death of other more salvageable casualties due to neglect. It is theorized that this additional category may provide a better means of staging expectant patients for care once resources become available; in addition, it may ease the process of triaging casualties to expectant status, as at least semantically, the blue category differs from the black category.

The ICRC system reflects the austerity and remoteness often encountered by ICRC personnel, as well as the limitations of healthcare systems in many developing countries. While the ICRC recognizes and references a METTAG variant (immediate, delayed, minimal, expectant), they have also employed a simpler, two-tiered system for settings where no surgical care is available locally. This methodology simply divides casualties by the determination of whether they require surgical intervention. Those needing surgery and who are anticipated to survive a journey are transported to the nearest available surgical facility, while nonsurgical and expectant casualties are provided care by existing local resources.

Most recently, the US Centers for Disease Control and Prevention convened an expert consensus panel to develop an optimized mass-casualty triage scheme.[105] The resulting product, referred to as the SALT system (Sort, Assess, Lifesaving Interventions, Triage/Treat/Transport), provides a model for a standardized, all-hazards model for triage. The model also integrates adult, child, and special populations into the single protocol. If implemented widely, it possesses the potential to improve interoperability and standardization of triage. Trials of relative efficacy and accuracy, along with the international community's response to this method, remain to be observed before recommendations regarding adoption of the SALT system for tactical medical use may be offered.

Reprise and Conclusion of Case Study

While the team is packaging the casualties for tactical evacuation, the medical officer observes, acquires, and engages the RPG gunner with small-arms fire, neutralizing him. The remaining insurgents disengage after receiving fire from the convoy's crew-served weapons (M-2 heavy machine guns). Hasty tourniquets are applied to bleeding extremity wounds on both casualties, followed by performance of rapid secondary surveys. Both casualties possess patent airways and are conscious. The casualty with blunt thoracic trauma has clinical signs of multiple rib fractures, but no flail segment is present, there is no jugular venous distention, the trachea is midline, and the affected hemithorax is resonant upon percussion. The casualties are loaded into an operating HMMWV escorted by the medical officer. After hastily attaching the disabled HMMWV to an operating vehicle via a tow rope, the convoy proceeds at top speed to the nearest forward operating base where the casualties are further stabilized. On arrival at the Battalion Aid Station, the staff radios a nine-line MEDEVAC request. The casualty with the isolated penetrating wound to the forearm receives a hemostatic dressing and direct pressure, which provides adequate hemostasis. The other casualty receives a tube thoracostomy, with approximately 30 milliliters of blood drained after placement. Both receive intravenous morphine and ceftriaxone, and both are packaged on stretchers with warm blankets. Tactical Combat Casualty Care casualty cards (DA Form 7656) are prepared and appended with clinical and treatment data. Subsequently, they undergo air MEDEVAC to a CSH. Both survive, are evacuated to the continental US, and eventually return to duty with their unit prior to rotation home.

Future Directions

The practice of out-of-hospital CCC is poised for dramatic change. Senior military leadership, military medical thought leaders, and combat casualty researchers have arrived at a collective agreement that the out-of-hospital phase of care (Roles I and II) is the place where the next "great leap" in casualty survival will be realized. Innovations in technology, training, medical direction, and communications will occur. Future solutions may include field-deployable blood components and procoagulants designed to prevent or mitigate traumatic coagulopathy and improve tissue oxygenation. These first steps toward a system of remote damage control resuscitation hold great promise and may decrease prehospital mortality and postoperative multiorgan system failure. The development of tactical medical information systems is an area of intense focus. The eventual goal is reliably capturing out-of-hospital physiologic and therapeutic data. This data will improve training and support of CCC providers, as well as help to define future research agendas. Perhaps most exciting is the potential for developing integrated and graduated out-of-hospital CCC. This would combine professional medical oversight and real-time decision support with skilled resuscitation teams and critical care air transport capability for MEDEVAC units. While integration and implementation of this "Combat EMS System" will prove challenging, the successes of past and current CCC providers – coupled with the aforementioned research and development foci – may set the conditions for this "next great leap."

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