Chapter 3

MILITARY PREHOSPITAL MEDICINE

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INTRODUCTION

In Afghanistan, the long distances, restriction of movement on the ground, and domination of the airspace by the coalition have made helicopters essential in both moving and treating casualties in the prehospital battlefield arena. The difficulty now faced is identifying which aspects of care have led to improved patient survival and how to apply these lessons in future conflicts.

The military medical evacuation system has significantly evolved in the past 11 years with a change from step-wise movement of casualties through the different echelons of care to the present practice of direct transfer from point of injury to Role 2 or 3 hospitals. All areas of military medical care have improved, and the evacuation chain of survival for the combat casualty is now highly evolved. Between April 2, 2006, and July 30, 2008, 85 patients who were predicted to die from massive injuries sustained in the fighting in Afghanistan survived.[1] The combined medical services of all nations in Afghanistan continue to produce statistically unexpected survivors from trauma. Soldiers are now surviving injuries that would have been uniformly fatal in previous conflicts.

This evolution has led to a complex system of systems within areas of Afghanistan (the most current example) in which all forms of CASEVAC (the movement of casualties aboard nonmedical vehicles or aircraft) and MEDEVAC (the movement of casualties via ground or air by a dedicated medical evacuation platform) may be employed in the course of providing combat casualty care. A patient may arrive at a Role 2 or 3 medical treatment facility (MTF) aboard just about any platform, having received a wide range of en-route care interventions. The spectrum of care ranges from ground vehicles of opportunity providing no en-route care at all to an armed and armored CH-47 helicopter with a four-person medical emergency response team, led by a doctor experienced in prehospital care and equipped to perform extensive resuscitation en route.

Currently in parts of Afghanistan, at least three different systems of forward aeromedical evacuation may be operating: US Army MEDEVAC helicopters (known since the Vietnam War as "Dustoff"), US Air Force Pararescue helicopters (referred to as "Pedro"), and the United Kingdom (UK) Medical Emergency Response Team (MERT) aboard CH-47 aircraft. This mixture of forward aeromedical evacuation capabilities is in addition to various means of ground evacuation that may be employed as dictated by weather, threat, or other considerations.

These capabilities are employed in individual missions through a system of "intelligent medical direction" or "intelligent tasking," which normally resides in the Combined Joint Operations Center of the regional command and is directed by a patient evacuation coordination center (PECC). PECCs are staffed by experts in medical and aviation operations and often include a person with clinical expertise, usually a nurse. The detailed processes at work in a PECC are beyond the scope of this chapter but serve overall to assure that the goals of "right patient, right platform, right escort, right time, right destination" are all achieved. These five "rights" give casualties the greatest possible chance to survive and medical professionals the greatest possible chance to apply their expertise in caring for them. Given the wide variation among different evacuation platforms, it behooves the medical professional to have some familiarity with their various capabilities to be prepared to receive patients ranging from those who received no en-route care at all to those who were fully resuscitated prior to arrival at the MTF.

It is likely that in the next war, the environment, the threat, and the platforms used to evacuate casualties will be different. The various evacuation capabilities, from ground CASEVAC to MERT or even some capabilities more complex than are presently feasible, will need to evolve to continue providing life-saving care for service members. The lessons learned on (and over) the plains and mountains of Afghanistan may also have application in the civilian arena, particularly in areas where trauma systems are in a state of continuous evolution. The current Joint Theater Trauma System, built in the combined and joint environment of Afghanistan, is achieving unprecedented levels of performance and saving a larger proportion of seriously injured combat casualties than in any previous conflict.

THE EVACUATION CHAIN

The Chain of Survival

The delivery of critical care forward of the hospital must be placed within the wider continuum of care. Of the many available multinational prehospital evacuation assets, the helicopter-based medical care forms are the most widely used within the chain of evacuation from the battlefield to Role 3. Without immediate and effective first aid at the point of injury, none of the most critically wounded would survive to be evacuated.

The first link in the chain of survival requires soldiers (referring here to any service member) to treat themselves or for a buddy to apply first aid.

Self Treatment

All soldiers are taught basic first aid. This training is comprised of triage, basic life support, pressure dressings and tourniquets, placement of chest seals, use of the sit-up and lean forward position for oral cavity and oropharyngeal hemorrhage, and administration of the combat pill pack (analgesics and antibiotics). The initial treatment is likely to be by the casualties themselves before any help arrives as mission priorities during a fire fight continue. The most common life-saving self treatment is applying a tourniquet for extremity hemorrhage.

Buddy-Buddy and Team Medics (UK)

For UK armed forces the next phase of care is provided by other soldiers. The "buddy-buddy" system simply allows the same level of care to be provided by those uninjured or less injured than the casualty. A minimum of one in every four soldiers will be trained to the level of team medic, with a higher level of first aid training and usually carrying additional medical items such as intravenous (IV) cannulae; however, this soldier's primary role is not medical. Training is based on British "CABC" military trauma management: treatment of Catastrophic or massive hemorrhage, including the use of tourniquets; Airway; Breathing; and Circulation. The emphasis at this stage is on control of catastrophic hemorrhage. Communication and organizing the evacuation of the casualty down the chain are concurrent activities. Many patrols also include a combat medical technician, a professional medic with the skills to deliver more advanced techniques if necessary, such as vascular access, pelvic splints, and airway management.

Combat Casualty Care (US)

The equivalent stage in US forces is termed combat casualty care or sometimes care under fire, which also begins at the point of injury. Medical care is administered by either the injured casualty (self-care) or by buddy care via a fellow combatant with no specific medical training, or an individual with basic first aid skills training, termed a combat lifesaver. Specific combat units may have medical technicians with specific entry level or advanced training embedded in their ranks for the purpose of providing more advanced care at the point of injury (eg, combat medic, Special Forces medical technician or sergeant, pararescueman, corpsman).

Higher Levels of Care (Roles 1 through 3)

Rapid evacuation of casualties is a priority because it increases casualty survival and allows units to continue the mission once the wounded are removed. The traditional UK military evacuation of casualties occurs through Role 1, a mobile, lightly equipped unit consisting of a doctor and a number of medics called a regimental aid post (RAP). Each battalion has one RAP, which is typically augmented by another physician and additional medics in certain areas of operations. The United States has Role I MTFs, most commonly termed a battalion aid station (BAS). This unit, comparable to the RAP, conducts triage, resuscitation, and simple life-saving interventions, and facilitates evacuation to a higher level of care. The BAS is staffed by a physician or physician assistant as well as medics, and again like the RAP has few patient hold capabilities and no surgical capabilities. The BAS is typically collocated far forward with a maneuver unit and is able to stabilize casualties for evacuation to higher roles and facilitate return to duty when appropriate.

The next stage in the UK is Role 2, a mobile surgical facility commonly described as a forward surgical team, typically consisting of two surgeons, two anesthetists, an emergency physician, and variable numbers of medics, operating room staff, nurses, and support staff. It commonly has two operating tables, and its main aim is to provide damage control surgery with a limited capacity for equipment and blood products. Rarely does this unit have any patient holding capability, and its ability to provide life- or limb-saving surgery is dependent on efficient evacuation to the next level. Role 3 is a field hospital with variable capacity depending on the predicted need and casualty estimate, normally with at least an emergency department, two operating tables, four critical care beds, and twenty-five other beds with the appropriate staff.

The US Role 2 MTF, in addition to basic primary care capabilities, can provide blood transfusion (typically uncross-matched blood), brief inpatient admission, dental and mental health, and when augmented, damage control surgical services. According to the *Emergency War Surgery Handbook*,[2] Role 2 MTFs with surgical capabilities can conduct life-saving general, thoracic, vascular, orthopedic, and neurosurgical procedures. This surgery is focused on hemorrhage control, control of contamination, and overall stabilization. These augmented units include the US Army forward surgical team, which has one orthopedist, three general surgeons, two nurse anesthetists, and two critical care

Figure 3-1. Boeing CH-47 Chinook helicopter. Reproduced from: http://upload.wikimedia.org/wikipedia/commons/4/41/CH-47F_at_NTC_2008.jpg

Figure 3-2. Sikorsky UH-60M Black Hawk helicopter.

nurses and technicians. Capabilities include the ability to conduct 30 surgical procedures over a 72-hour period and postoperative intensive care bedding for up to eight casualties over a 6-hour period. Other mobile forward surgical teams include the US Air Force mobile field surgical team (a 5-person team capable of 10 damage control procedures over 48-hour period), and the US Navy surgical company (3 operating theaters with a 60-bed capacity and a 72-hour holding period).

Evacuation to Higher Level of Care

In Afghanistan, the classical concept of care delivered in a linear fashion from point of wounding through Roles 1 and 2 before evacuation to Role 3 and beyond no longer necessarily applies. The exception to this is in areas of the country where time and distance factors between units on the ground, Roles 1 and 2 MTFs, and definitive care at Role 3 dictate making stops along the way to stabilize or resuscitate patients prior to onward evacuation. The majority of casualties, however, are retrieved from the battlefield and rapidly evacuated via aircraft to the nearest Role 3 hospital, bypassing smaller medical facilities. Often confounding evacuation methods is the ever-present enemy threat to a valuable evacuation asset sitting on the ground vulnerable to small arms fire. There is a mix of airframes, ranging from a spacious CH-47 (Figure 3-1) to a more space-limited UH-60 (Figure 3-2) platform. (The UH-60 focuses on the "scoop-and-run" concept, whereas the space in the CH-47 allows resuscitation to occur in flight, combining "scoop-and-run" with the "stay-and-play" concept.) Ultimately decisions about whether to begin treatment on the ground or immediately launch and provide care en-route are made on the aircraft by the pilot in command with input from the medical team in the back, soldiers providing protective fire on the ground or in the air, and the pilot's command and control element. For the last 5 years in Afghanistan, very little patient care has been provided by medical evacuation assets on the ground and most care has been performed in flight, with the exception of extreme circumstances such as casualties trapped in vehicles or mine fields.

The majority of casualties will be delivered to the nearest Role 3 facility. However, a small number will benefit from primary evacuation to other facilities with specialist capabilities such as neurosurgery and ophthalmic surgery. Individual aircrews must be aware of available assets to facilitate decisions on the best facility for individual patients and ensure that timelines, especially for neurosurgery, can be met. Also, evacuating local nationals with certain injuries to host nation medical facilities helps prevent military facilities from becoming overwhelmed. Such decisions must be made rapidly and accurately and depend on the wider tactical picture, the number of casualties, the pattern of injury, and the experience of the individuals.

The remainder of this chapter will describe the three major platforms providing helicopter-based medical evacuation support to combatant forces in a theater of operation (currently Afghanistan): (1) the UK's CH-47-based MERT, (2) the US Army's UH-60–based Dustoff, and (3) the US Air Force's UH-60–based Pedro.

THE MEDICAL EMERGENCY RESPONSE TEAM

The MERT concept has evolved since 2006. In previous operational theaters (Northern Ireland, the Balkans, and Iraq), the Immediate Response Team (IRT), consisting of aircrew, the MERT, and the Force Protection

Teams (at minimum) was used, but the high numbers of casualties sustained in southern Afghanistan has driven the development of the IRT's medical component. A standing team consisting of a nurse, a paramedic, and a combat medical technician was, when required, supplemented by a hospital clinician; this team was known as enhanced MERT or MERT(E). Beginning in 2008, doctors were deployed specifically to be part of a MERT. Using doctors experienced in prehospital emergency medicine allowed higher level interventions such as thoracostomy, rapid sequence induction (RSI) of anesthesia, and prehospital blood component transfusion, as well as rapid senior-level decision making. At the same time MERT standard operating procedures (SOPs) were written to standardize the training given to the teams and the care given to patients.

Composition of the Team

There are usually two MERTS deployed to cover the British area of operations in Afghanistan, with a third team on standby in the UK. Currently one team consists of four personnel (Table 3-1). Although combat medical technicians work well within the teams, an effort is underway to deploy more trained paramedics as the fourth practitioner, giving them the opportunity to work under the supervision of a more experienced paramedic during their first deployment.

Predeployment Preparation

All team members have experience in civilian prehospital care. A combination of civilian courses such as Advanced Paediatric Life Support (APLS) and military medical courses such as Battlefield Advanced Trauma Life Support (BATLS), together with specialty courses, provide a platform on which to build integrated team training. These elements are brought together in the MERT course, in which teams are exposed to treating simulated casualties in increasingly challenging environments, with a final assessment on board a flying CH-47 in United Kingdom. Training is further consolidated at the whole-hospital predeployment exercise, in which simulated casualties are transferred to the hospital from a simulated Role 1 or point-of-wounding environment with subsequent resuscitation.

In-Theater Training

Once in the deployed setting, teams receive generic training to allow team members to refresh their skills and receive updates on the current tactical and clinical

TABLE 3-1

COMPOSITION OF THE MEDICAL EMERGENCY RESPONSE TEAM

Clinician	Background	Responsibilities
Flight doctor	Consultant or senior registrar (post-fellowship) in anesthesia or emergency medicine. Experienced in prehospital emergency medicine. HEMS doctor. Should have prehospital care as part of their job plan when not deployed.	Clinical leadership of the team. Senior decision-making. Control of hemorrhage, sedation, anesthesia, intubation, transfusion, packaging, and management of the patient in flight.
Flight nurse	Registered emergency medicine nurse. Should be experienced and clinically current. Civilian prehospital experience desirable but not always possible.	Administration of the team. IV/IO access, monitoring of the patient, blood component transfusion. Assisting during induction of anesthesia. Communications, especially between MERT and aircrew.
Flight paramedic	State registered paramedic. Regular work as a paramedic must be part of their job plan when not deployed.	Handover of the patient from the ground call sign. Loading and unloading of patients. Control of catastrophic hemorrhage. IV/IO access, assisting in blood component transfusion. Patient packaging. Handover to the hospital trauma team.
Fourth practitioner	In recent years this is usually a more junior paramedic, also state registered. Other team members fulfilling this role have included operating department practitioners and combat medical technicians.	Handover of the patient from the ground call sign. Loading and unloading of patients. Control of catastrophic hemorrhage. IV/IO access, assisting in blood component transfusion. Patient packaging. Handover to the hospital trauma team.

HEMS: Helicopter Emergency Medical System
IV/IO: intravenous/intraosseous
MERT: Medical Emergency Response Team

situation, before moving on to the team integration and familiarization phase. An appreciation of the multinational forces and differences in their SOPs is also presented. The location of all medical assets and their capabilities, both military and local national facilities, is briefed to aid in correctly directing patients to facilities with the appropriate capabilities for their injuries.

Combat Casualty Retrieval

The IRT is on permanent standby to move. Response times are necessarily longer at night due to the requirement for extra mission planning, but the team aims to be airborne in a matter of minutes following receipt of a casualty report. In addition to the minimum MERT personnel, other elements such as combat troops, explosive ordnance disposal specialists, and fire fighters are available, depending on mission requirements. When on standby, the teams live together, close to the airframe, to facilitate communication and mutual understanding and to minimize response times.

US MEDICAL EVACUATION ASSETS

In Afghanistan the majority of casualties are carried by US medical evacuation assets. These assets may be ground or air platforms as the terrain and tactical situation dictates. Evacuation by air is the preferred means when possible.

CASEVAC

Because CASEVAC occurs on nonmedical vehicles or aircraft, en-route care beyond self-care or buddy care (tourniquets, IV, or intraosseous [IO] access) may be limited. A key distinction between CASEVAC and MEDEVAC is that only MEDEVAC platforms are identified by the Red Cross and thus enjoy protections under the Geneva Conventions. CASEVAC is rarely used in the current theaters of operations, although it is necessary when no MEDEVAC assets are available but combat aircraft are in proximity to casualties.

MEDEVAC (Dustoff)

Although the term “MEDEVAC” is commonly understood to refer to dedicated US Army air ambulances (known since the Vietnam War as “Dustoff” aircraft), medical evacuation is technically defined as the movement of patients by dedicated air or ground platforms with care provided en route. Medical evacuation may be from the point of injury, a casualty collection point, an ambulance exchange point, or from one treatment facility to another. Ground evacuation platforms differ based on the type of unit; ie, the M113A3 ambulance in armor, mechanized, and cavalry units provides direct medical support to their parent organizations, and light vehicles, M996 or M997 HMMWVs, are used in light infantry units. Throughout Operations Enduring Freedom and Iraqi Freedom, medical evacuation has been primarily conducted by MEDEVAC aircraft on an area basis utilizing HH-60M Blackhawk helicopters due to their speed, the geographical emplacement of forces, the restrictive terrain, and enemy use of improvised explosive devices. MEDEVAC ground and air platforms are identified with a red cross and operate completely unarmed except for the defensive personal weapons assigned to each crew member (tactical commanders may limit the display of the red cross according to operational and tactical circumstances). MEDEVAC platforms may be escorted by combat vehicles or aircraft as the tactical situation requires.

Training

En-route care is provided by a flight medic with a minimum emergency medical technician-basic (EMT-B) certification. Flight medics trained by the US Army School of Aviation Medicine receive advanced training and certifications such as Advanced Cardiac Life Support, International Trauma Life Support, and Pediatric Education for Pre-hospital Professionals or Pediatric Advanced Life Support, as well as courses in critical care management of a patient in a medical evacuation aircraft platform, RSI, helicopter underwater egress, high altitude operations, personal recovery operations, survival, and canine trauma management. The Joint Enroute Care Course, optional for flight medics, covers quality en-route care for a postoperative critical care patient. As a result of a recent initiative by the Army Medical Department, EMT-Paramedic certified flight paramedics are currently being fielded throughout the operational force.

En-Route Care

With a heritage dating to the first helicopter rescue in 1945, Dustoff is the only dedicated aeromedical evacuation platform with its own equipment, personnel, and doctrine within the armed forces. The scope of care flight medics can provide varies by unit and training, and is outlined in the unit’s treatment protocols, which are developed by brigade or battalion flight surgeons. EMT-B–trained flight medics can provide basic resuscitative and treatment capabilities including tourniquet application, infusion of crystalloid and colloid fluids, splinting (including pelvis), pain management, basic airway management (bag-valve mask and laryngeal mask airway), defibrillation, and needle decompression. Due to the frequent transfers of critically injured, mechanically ventilated casualties between Roles 2 to 3 MTF, an emerging tactic, technique, or procedure (TTP) calls for some Dustoff crews to be augmented by an en-route critical care nurse (ECCN) or flight surgeon/aviation physician assistant to provide postoperative en-route critical care.

Capabilities

US Army Dustoff units are assigned 15 aircraft and are placed as far forward as possible. Typically, forward support MEDEVAC teams have three aircraft and are collocated with an aviation task force. Urgent and urgent surgical missions are mandated to be complete in 60 minutes (the "golden hour") from the time the unit receives the mission to the patient's delivery to the appropriate MTF. This is a recent change in doctrine based on a 2009 Secretary of Defense Memo for Record. The memo also spelled out a launch goal of under 15 minutes from time of mission receipt to aircraft launch.

The placement of MEDEVAC aircraft in theater is critical due to the austere and distant locations of some US and coalition forces. Because of the wide dispersal of forces and finite MEDEVAC aircraft available, commanders must accept certain risks to accomplish the overall mission. MEDEVAC aircraft are positioned in conjunction with the population at risk, enemy threat, and mission requirements. The location of MEDEVAC aircraft is closely synchronized with medical assets that have resuscitative surgical capability. MEDEVAC companies are organized within general support aviation battalions in each Combat Aviation Brigade and provide area or direct support as directed. The HH-60 is a two-pilot aircraft staffed with a Medical Service Corps officer and warrant officer conducting flight operations, and one crew chief (15T) and one flight medic (68WF) occupying the cabin area. Patient capacity ranges from two to six litter patients (based on configuration) and up to eleven ambulatory patients. The cabin area of the aircraft is modified for medical treatment to include an internal or external hoist with a forest penetrator and litter system, a medical equipment set, and auxiliary oxygen.

TTPs continue to evolve in an effort to increase favorable patient outcomes and reduce morbidity. ECCNs have been utilized on a limited basis in Operation Enduring Freedom for the evacuation of high acuity patients from Role 2 to Role 3 MTFs to enhance survivability. As of this writing, one class of the Critical Care Flight Paramedic program has graduated, with planning for a total of 950 graduates by 2018. Enhancing en-route care capabilities, graduates from the new course are given 1,100 additional training hours and are capable of administering blood products when authorized by a physician or physician assistant.

US Air Force Pararescue

History and Description of the Platform

The Air Rescue Service was an outgrowth of the need for an organized rescue asset after World War II, when airframe and aircrew losses and crashes in remote and austere environments were extensive. The initial aircrew focused on remote survival and basic medical support after physicians, who were initially involved, were removed. During the Vietnam War the capabilities included rescue of downed aircrew and rescues during active fire fights. This led to the formal introduction of tactical training for the pararescuemen (known as "PJs"). The call sign "Pedro" (used by an air rescue squadron in Laredo, TX, in the 1950s) was adopted in 1967. In the 1990s pararescuemen began obtaining paramedic certification, which remains the current foundation of their medical education, with further specialized supplementation.

US Air Force air rescue is comprised of the HH-60 helicopter (Pedro), fixed-wing HC-130P Hercules (Fever), and the Guardian Angel Weapon System (GAWS), staffed by pararescuemen and combat rescue officers. The primary role of Air Force rescue is personnel recovery, including combat search and rescue and the recovery of isolated personnel (traditionally referring to downed pilots and aircrew in remote or nonpermissive environments). Due to the infrequency of aircraft loss and the Army's need to meet the golden hour requirement, Pedro has augmented tactical evacuation. The pararescue airframe is the US Air Force HH-60G Pave Hawk helicopter (Figure 3-3). The helicopters fly in pairs and have two or three pararescuemen each. Pararescuemen are US Air Force special operating forces trained to the level of EMT-P, with the ability to perform advanced airway management (bag-valve mask, laryngeal mask airway, endotracheal intubation, surgical airways), IO access, tourniquet placement, splinting (including pelvis), pain management, needle decompression, finger and tube thoracostomy, and (since December 2010) transfusion of uncross-matched red blood cells and plasma.

Fever, an intratheater MEDEVAC asset deployed

Figure 3-3. US Air Force HH-60G Pave Hawk helicopter.

to Camp Bastion, Helmand Province, is equipped to move critically injured patients to a Role 3 MTF from an airstrip in proximity to a Role 1 or 2 facility. The medical crew was originally made up of a US Air Force flight surgeon and two pararescuemen, but was recently augmented by an emergency medicine doctor and critical care nurse (ECCN). Capabilities include advanced en-route critical care with ventilator and hemodynamic support. Fever evolved due to the necessity to evacuate casualties from remote locations, often after damage control surgery, to a Role 3 MTF more rapidly than possible with rotary wing aircraft. The airframe can carry multiple litter patients (up to nine), allowing evacuation of multiple casualties from an overwhelmed Role 1 or 2 facility, and does not need en-route refueling in Afghanistan.

The primary role of the GAWS is personnel recovery. The GAWS is composed of combat rescue officers and pararescuemen. To carry out personnel recovery for the Department of Defense, pararescuemen are trained as the most advanced tactical and technical rescue specialists in the world. Pararescuemen are paramedics with supplemental training in tactical medicine and evacuation, advanced care for extended times in remote and austere environments, and in-flight care on fixed or rotary wing aircraft. Other capabilities include precision parachuting, scuba diving and surface marine operations, rescue swimmer, weapons and small unit tactics, communications, small vehicle and water craft use, high altitude and cold weather operations, alternate means of insertion and extraction via rotary wing aircraft, and multiple rescue skills including confined space, high angle, swift water, vehicle extrication, fire suppression, and structural collapse. Because of the need to maintain these capabilities, clinical medical training is limited. However, pararescuemen are able to go into conflicts with active enemy contact and effect rescues of injured personnel that the other platforms cannot.

Pararescue Medicine

Pararescue medicine is a unique conglomerate of EMT-P certification, Tactical Combat Casualty Care (TCCC), Special Operations medicine, wilderness medicine, dive medicine, and en-route care in flight. TCCC care is formally recognized by the National Association of Emergency Medical Technicians. It includes three phases: (1) care under fire, (2) tactical field care, and (3) tactical evacuation. Pararescuemen are the only medical asset to routinely provide care during all phases. TCCC began as an empiric approach to combat injury care in 1997 but was recently validated in a report by Kotwol[3] and now represents evidence-based medicine. TCCC is based on data on the use of tourniquets, gauze impregnated with hemostatic agents, early antibiotics, and surgical airways for severe maxillofacial trauma. This approach has the potential to fundamentally transform civilian prehospital trauma care.

CARE DURING MEDEVAC

Because the MERT includes a highly qualified doctor and the adequate space to carry out highly skilled interventions, the medical team on board are able to bring damage control resuscitation and trauma anesthesia out of the hospital, to the patient during evacuation. This ability to carry out advanced resuscitation has been termed by some US authors as "advanced medical retrieval" (AMR), and they have used this term in comparing MERT to more conventional military retrieval methods. Recent studies by these authors comparing, among other things, mortality among casualties evacuated by these different capabilities indicate that conventional platforms are effective when patients have a low injury severity level.[4–7] However, the studies found evidence that a definable injury severity exists for which evacuation with an AMR capability is statistically associated with improved outcomes. They also discovered that over all injury severity scores, there was a lower than predicted mortality on an AMR platform.[4,7] Interventions carried out aboard AMR platforms tended also to be associated with shorter times between arrival at the emergency department of the receiving MTF and entering the operating room for surgery,[4] and shorter times to initiation of resuscitation.[6] Discussed below are some of the issues facing combat casualty care aboard platforms used for evacuation.

Concurrent Resuscitation

Aboard larger aircraft with multiple medically trained personnel on the crew, the concept of concurrent resuscitation becomes possible, as described best by MERT team members. As soon as the patient touches down on the deck of the aircraft, treatment begins. Because of injury severity in a significant number of these casualties, there is no place for the "vertical" assessment of the patient through a rigid protocol; instead, these steps must happen simultaneously in a "horizontal" fashion (as though the patient is a racing car and the medical team the pit crew). With training and practice medical teams can apply tourniquets, dressings, and a pelvic binder; initiate monitoring; intubate and ventilate the patient; and administer at least four units of warmed blood components in the space of 6 minutes. This can happen only when all members of the team know their exact roles and work quickly and efficiently together.

Control of Catastrophic External Hemorrhage

Stopping external hemorrhage is a key element in reducing mortality associated with blast injury. In the case of traumatic amputations this is most commonly achieved by the rapid application of a tourniquet to the injured limb or limbs by the patient, other soldiers, or a team medic. Once the patient is on board the airframe, tourniquets are checked and when necessary tightened and additional tourniquets placed. Experience has taught that patients with above-knee amputation will require two combat application tourniquets applied side-by-side to ensure that hemorrhage control is achieved. Stumps are placed in a box splint to protect them and to exploit the analgesic effect of immobilization. Hemostatic agents such as Celox (MedTrade Products Ltd, Crewe, UK) followed by 5 minutes of direct pressure may be required on areas of noncompressible hemorrhage, particularly the junctional areas of the neck, the axillae, and the groin. Because a high frequency of pelvic injuries is associated with traumatic amputations,[8] pelvic ring injury should be suspected and treated prophylactically using a pelvic binder in all lower limb traumatic amputations. Perineal injuries are common, particularly in high amputations, and require aggressive packing with hemostatic agents to successfully control bleeding.

The Log Roll

Use of the log roll assessment technique is controversial. The patient will benefit from minimal movement during this phase of their injury: clots have not yet consolidated and fractures are not stabilized. However, missing a penetrating injury to the back of the head or chest, or missing an area of external hemorrhage, is considered to be more dangerous for the patient than being moved, so a single log roll is mandated. Hemostatic agents must be on hand during the procedure, and particular care must be taken not to dislodge IV and IO cannulae and the endotracheal tube.

Access to the Vascular Space

While the priority for treatment firmly rests with hemorrhage control, in practice, at the same time as the tourniquets are being checked, access to the intravascular space is being gained. Large-bore peripheral IV cannulation is ideal because high flow rates can be achieved; however, it is difficult, time-consuming, and associated with high failure rates due to the environmental constraints of operating on airframes and the extreme hypovolemia seen in MEDEVAC casualties. IO access using the EZ-IO (Vidacare, Shavano Park, TX; see Chapter 39, Basics of Pediatric Trauma Critical Care Management, Figure 39-4) and FAST (Pyng Medical, Richmond, Canada) is therefore routine due to the speed, reliability, and lower failure rates of these devices. The EZ-IO is most commonly placed in the humeral head in the military population due to the high frequency of injuries to the legs and to take advantage of the higher flow rates.[9] EZ-IO can be placed in the tibia or pelvic crest, if possible, but consideration should be given to major venous injury in thoracic and abdominal injury. FAST is placed in the sternum. While it can be used for blood products, it is principally used for the administration of drugs. All blood products must to be warmed prior to administration and are administered via an enFlow (Vital Signs Inc, Totawa, NJ) warming device using a 50 mL-syringe and a 3-way tap. Although IO access can in theory remain in use for up to 24 hours, it will be superseded by the insertion of central venous trauma lines immediately on arrival at the Role 3 hospital.

The Gold Standard (Rapid Sequence Induction)

The MERT is one of the few teams around the world that performs drug-assisted intubation on board a helicopter while in flight. Most civilian Helicopter Emergency Medical System (HEMS) teams argue that patients should be fully stabilized and packaged before movement by helicopter. However, civilian helicopters are smaller than military combat support helicopters and have limited interior space to perform procedures. The use of large-body helicopters, particularly the CH-47, makes it possible to gain good 360° access to the patient, to carry large amounts of equipment including monitoring devices, and to perform intubation safely. Although there are known advantages to techniques such as prehospital anesthesia, patient outcome following trauma is directly related to the time between injury and surgical intervention. Performing procedures on the aircraft while in flight reconciles both of these approaches.

Severely injured patients will require more than one route of intravascular access in order to administer anesthetic agents concurrently with starting the massive blood transfusion. This may be peripheral intravenous access, intraosseous access, or a combination of the two. Ideally the patient should be preoxygenated before drugs are administered. The patient should be monitored with pulse oximetry, 3/4-lead electrocardiogram, noninvasive blood pressure, and end-tidal CO_2 at a minimum. A set of observations should be recorded before RSI is carried out. The patient should be intubated by the most experienced practitioner (the flight doctor), assisted by a trained assistant (the flight nurse). Endotracheal tube placement must be confirmed by capnometry or (preferably) capnography. Monitoring must be continued during flight and during handover to the hospital trauma team.

Ideally, the entire team will be focused on delivering care involving RSI to one patient, enabling the high standards described above to be met. Frequently, however, multiple patients require RSI on the same mission. In these circumstances the flight doctor must decide whether or not performing RSI on one patient will compromise the management of the others.

Constraints in Flight

There are clear difficulties with performing RSI in the back of a helicopter moving tactically. A formal risk assessment register is maintained in theater, and every effort made to mitigate the threats identified. Some examples are listed in Table 3-2.

TABLE 3-2

RISKS OF RAPID SEQUENCE INDUCTION DURING FLIGHT

Risk	Mitigation
Enemy action on the ground	The MERT is escorted by a Force Protection Team. Time on the ground collecting patients is kept to a bare minimum. All team members must pass generic predeployment fitness and military tests.
Enemy action against the aircraft	Use of armed and armoured military aircraft. Specific risks are addressed by Joint Helicopter Command. Where possible the aircraft flies tactically or at an altitude higher than enemy munitions can reach. Team wears full category 3 personal protective equipment, including ballistic helmet, eyewear, and body armor.
Aircraft noise	Team is issued personal role radios cleared for use in flight, with noise cancelling headsets. Hand signals used as backup.
Aircraft movement	Predeployment training includes training in flight on CH-47 aircraft. Equipment is secured. Good communication with the pilots.
Extremes of temperature	Equipment is ruggedized. Patient warming with Blizzard Blanket* and fluids warmed with enFlow.† Awareness of heat injury risk. Drugs and equipments such as pediatric endotracheal tubes that soften in high temperatures are kept in a cool box.
Darkness	Team is equipped with night vision equipment and blue filtered torches. Limitations of these are understood. All monitoring equipment is visible in darkness (with LEDs or backlit screens). Bags are secured in standard way to facilitate locating equipment.
Multiple taskings	Missions may change in flight. Plenty of backup equipment is stored onboard the aircraft.

*Blizzard Protection Systems Ltd, Bethesda, Gwynedd, UK
†Vital Signs Inc, Totawa, NJ
LED: light-emitting diode

Indications for Rapid Sequence Induction

The decision to perform RSI on a patient must be made quickly by the flight doctor and communicated to the team. Ideally different clinicians and different teams would make similar decisions; however, some variability in decision-making is inevitable. Indications for intubation are similar, but not identical, to those used by civilian HEMS teams (Table 3-3). (Note that "crash" intubation of patients in cardiac arrest is a separate indication whereby intubation is performed in order to assist resuscitation. Drugs may not be required, so it is not considered part of RSI.) Two patterns of injury stand out:

TABLE 3-3

INDICATIONS FOR RAPID SEQUENCE INDUCTION BY MEDICAL EMERGENCY RESPONSE TEAMS

Indication	Discussion
Loss of airway, anticipated loss of the airway	Frank loss of airway or anticipated loss of airway, eg, in airway burns or catastrophic maxillofacial bleeding.
Respiratory failure	Assisting ventilation, eg, with flail chest or multiple penetrating chest injuries. However, converting a patient with chest injuries from negative to positive pressure ventilation is likely to cause further problems. Converting a pneumothorax to a tension pneumothorax must be anticipated.
Hemorrhage	Catastrophic hemorrhage itself is not a direct indication; however, these patients may have a diminished level of consciousness in addition to needing intubation and ventilation to reduce the physiological demands of shock. There are frequently concurrent indications for RSI.
Head injury	Blunt or penetrating head injury with reduced or falling GCS. Maintaining oxygenation, normocapnia, and blood pressure are a priority.
Humanitarian issues	The procedures required to stabilize a severely injured trauma patient such as tourniquets, IO access, and pelvic binding are frequently themselves distressing and painful. Performing RSI allows these to be carried out by the team rapidly without fear of causing the patient more pain. The levels of analgesia required for these patients may well require the airway to be secured.

GCS: Glasgow coma scale
IO: intraosseous
RSI: rapid sequence induction

1. **Traumatic amputee**. When improvised explosive devices detonate underneath or close to dismounted service members and result in double or triple limb amputation, patients are usually in shock, have multiple injuries including pelvic and spinal column disruption, and may be suffering from concomitant head injury. RSI is often necessary because ventilator compromise frequently is associated with massive polytrauma from blast.
2. **Penetrating head trauma**. Penetrating injury to the head from gunshot wound or high velocity shrapnel may well require early intubation. Any reduction in Glasgow coma scale alerts the team to a potential deterioration; the outcome from head injury is improved if falls in oxygenation or blood pressure are avoided. In addition, transfer times may be prolonged if the patient requires neurosurgical intervention. In these cases the patient may be flown directly to the neurosurgeon, who may be at a location further away.

Drugs Used With Intubation and Ventilation

The flight medical officer prepares drugs at the beginning of each shift. Syringes are drawn up in standard fashion, in standard concentrations, and are labelled. This time-saving measure allows the immediate administration of anesthetic agents when intravascular access has been gained on the casualty and reduces the risk of drug administration errors. Unused drugs must be wasted after 24 hours without use due to the risk of bacterial contamination. Standard MERT RSI is as follows:

- Ketamine induction, 1–2 mg/kg.
- Succinylcholine for muscular paralysis, 1.5–2.0 mg/kg.
- Continuation of anesthesia with aliquots of 1–2 mg morphine and 1–2 mg midazolam or ketamine, depending on the patient's physiology.
- Extension of paralysis with nondepolarizing neuromuscular blocking agent. Vecuronium 0.1 mg/kg has the advantage of not requiring refrigeration.

Ketamine is the main choice of induction agent. Ketamine has several applications and may be used for analgesia, procedural sedation, or induction of anesthesia. Many providers consider ketamine the first choice for trauma analgesia because of favorable properties compared to morphine. The advantage of ketamine for trauma induction is its relative cardiovascular stability: blood pressure does not fall on administration, which is considered beneficial in a patient population frequently presenting with hemorrhagic shock. Onset of anesthesia is relatively fast, and ketamine has a wide therapeutic-toxic range. Disadvantages of using ketamine include its chronotropic effect and stimulation of lacrimation and salivation, all of which may make the depth of anesthesia difficult to judge.

Succinylcholine remains the initial paralyzing agent of choice. There is a strong argument that in the airway compromised trauma patient population there is no option to discontinue induction and to wake the patient up in the event of a failed intubation. Therefore, longer acting neuromuscular blocking agents can be considered an appropriate choice in this environment.

Morphine and midazolam are useful to maintain anesthesia in the absence of gaseous anesthetic agents that would be impractical and dangerous in a combat environment. Morphine doubles as an analgesic agent for more minor casualties. Midazolam has a direct hypotensive effect, and its use should be carefully titrated to resuscitation status. However, this combination represents one of the most dangerous combinations on the battlefield and should be used with great care and only when one-on-one caregiver-to-patient care situations exist.

Fentanyl is a useful adjunct. It is used to mitigate the effect of laryngoscopy in patients with head injury and is a very effective analgesic for patients who are awake. Onset of action is fast and it can be administered nasally using a MAD Nasal (LMA, San Diego, CA) mucosal atomization device when needed.

Intubation

Improving the first-attempt intubation success rate is all important (Tables 3-4 and 3-5). To this end the most experienced practitioner (the flight doctor) performs the intubation, assisted by the flight nurse, who is trained in the drugs, equipment, and monitoring required to safely administer anesthesia. The patient is preoxygenated using 15 L/min via Hudson mask (Hudson RCI/Teleflex, Research Triangle Park, NC). Positive pressure ventilation during the preoxygenation phase (using the bag-valve-mask technique) is avoided whenever the patient is making respiratory effort. This avoids gastric insufflation with the consequent risk of vomiting and diaphragmatic splinting. Many patients will already have been administered high flow oxygen before loading onto the airframe.

Confirmation of Endotracheal Tube Position

Visualization of the endotracheal tube passing through the cords is the most obvious confirmation of successful placement. Visualization alone is not enough, however; confirmation of end-tidal CO_2 is mandatory. Several devices are available to provide redundancy (Table 3-6).

The flight nurse assists the flight doctor in applying monitoring equipment and measuring end-tidal CO_2. Once both are satisfied with the placement of the

TABLE 3-4

IMPROVING THE SUCCESS RATE OF INTUBATION

Factor	Best Case
Experience	Flight doctors are already experienced in prehospital anesthesia.
Training	All team members go through role-specific predeployment training. Training continues in theater.
Patient population	Generally fit service members; however, civilian casualties provide increased risk for difficult intubation.
Positioning	The flight doctor has space to move and will generally intubate in the lying or kneeling position.
Equipment	All prehospital intubations are carried out using either a stylet or gum-elastic bougie technique. Bougie intubation requires use of an assistant. Suction is on-hand.
Drugs	Unless cardiac arrest has been diagnosed, success rates are improved by consistent use of drugs to assist intubation.

TABLE 3-5

INTUBATION SUCCESS RATES FOR MEDICAL EMERGENCY RESPONSE TEAMS

	Civilian UK Emergency Department[1]	London HEMS[2]	MERT[3]
Mallampati Grade I or II view	92%	81%	96%
1st attempt	87.7%	87.5%	94.4%
1st or 2nd attempt	Data not available	97.8%	98.8%

HEMS: Helicopter Emergency Medical System
MERT: Medical Emergency Response Team
UK: United Kingdom
(1) Graham CA, Beard D, Oglesby AJ, et al. Rapid sequence intubation in Scottish urban emergency departments. *Emerg Med J.* 2003;20:3–5. (2) 11. Harris T, Lockey D. Success in physician prehospital rapid sequence intubation: what is the effect of base specialty and length of anaesthetic training? *Emerg Med J.* 2011;28:225–229. (3) Kehoe A, Jones A, Marcus S, et al. Current controversies in military pre-hospital critical care. *J R Army Med Corps*. 2011;157(3 Suppl 1):305–309.

TABLE 3-6

METHODS OF MEASURING END-TIDAL CO_2

Method	Description
Colorimetric capnography	Changes color within a few breaths, useful to confirm ETT placement in the initial stage and can then be discarded to remove dead space from the circuit.
EMMA* Emergency Capnometer	Lightweight device connecting in-line with the ETT. Measures CO_2 and displays a useful visible LED readout.
Side-stream or in-line capnography	The monitors used by MERT can display end-tidal CO_2 capnography. They are the gold standard and should be used on all intubated patients. CO_2 waveform provides useful information during resuscitation.

*Masimo, Danderyd, Sweden
ETT: endotracheal tube
LED: light-emitting diode
MERT: Medical Emergency Response Team

Figure 3-4. Thomas Tube Holder in use.
Thomas Tube Holder is a copyright of Laerdal Medical. Photo used with permission from Laerdal Medical. All rights reserved. Thomas Tube Holder is a copyright of Laerdal Medical. Photo used with permission from Laerdal Medical. All rights reserved.

endotracheal tube, the laryngoscope can be withdrawn from the patient's mouth and the tube secured, preferably using a Thomas Tube Holder (Laerdal Medical, Wappingers Falls, NY; Figure 3-4). A cervical collar and head blocks are usually applied, both to secure the cervical spine and to help prevent the endotracheal tube from becoming dislodged.

Failed Intubation Drills

Any indication that the endotracheal tube has been incorrectly placed mandates adherence to failed intubation drills. Extubation and a second attempt to intubate may be possible provided the patient's saturations can be maintained by bag-valve-mask ventilation. Rescue devices available include alternative laryngoscopy aids and supraglottic devices. The final common pathway is to perform a surgical airway. This technique must be practiced as a drill by the team so that when it does occur, the chances of success, and delivering a live patient to hospital, are maximized.

Ventilation

Aboard aircraft ventilation is usually achieved using a transport-style ventilator (Oxylog 1000, Draeger Medical, Hemel Hempstead, UK), which provides a constant minute volume with stability in end-tidal CO_2, a benefit in head-injured patients. The device also frees the doctor to perform other tasks. Some practitioners prefer to maintain a "feel" of the lung dynamics by continuous manual ventilation. A rise in airway pressures may herald the development of a tension pneumothorax.

Thoracostomy

Pneumothoraces are common in blast injury. Converting a patient from self-ventilation (negative-pressure ventilation) to positive-pressure ventilation is a high-risk strategy. A small pneumothorax may become larger or may become a tension pneumothorax. The entire team must be aware of this possibility at the moment of intubation and be ready to perform thoracostomies, bilateral if necessary, to relieve tension pneumothorax. During short transfers thoracostomies alone will be adequate, provided they are re-fingered when necessary. During longer transfers or to maintain the patency of the incision, battlefield chest drains can be inserted. Note that in self-ventilating patients, chest drains must be used.

Resuscitation

MERT has pioneered the administration of blood products in flight since 2008. Crystalloid fluid resuscitation is now rarely used in the context of major hemorrhage; rather, the focus is on replacing blood loss with blood products. This minimizes dilutional coagulopathy and reduces pathophysiological triggers for the acute coagulopathy of trauma by ensuring adequate perfusion and maintaining tissue oxygen delivery. The triggers for transfusion are:

- absence of a radial pulse,
- tachycardia over 120 bpm,
- anticipation of massive transfusion, or
- pattern of injuries (two or more or more amputations or penetrating torso trauma associated with changes in the vital signs).

Hypotensive Resuscitation

Traditional prehospital guidelines were to maintain a radial pulse or systolic blood pressure of 90 mm Hg until the patient reached the surgeon. The reasoning behind this method was to achieve a balance between maintaining organ perfusion and allowing a clot to form on the injured area. However, traumatic hemorrhage models involving blast have shown that maintaining these conditions for over an hour is detrimental, and casualty survival diminishes significantly with increasing acidosis.[10]

Novel Hybrid Resuscitation

Novel hybrid resuscitation has been shown to improve survival of traumatic blast casualties. It entails a goal of hypotensive resuscitation initially—achieving a radial pulse or a systolic blood pressure of 90 mm Hg—followed by the reestablishment of normotension thereafter. Exceptions to hypotensive resuscitation include head injury and pregnancy. The hypotensive phase of this resuscitation approach should last no more than 1 hour from time of injury. If at any time the patient begins to show signs of metabolic deterioration, the hypotensive resuscitation protocol should be stopped.

Blood Product Administration

Blood products are carefully regulated in keeping with best practices. Blood products are kept in specially designed "Golden Hour" boxes to maintain integrity of temperature control; the boxes may not be opened until the blood products are needed. The transfusion is administered in a 1:1 ratio of O negative packed red cells and AB positive fresh frozen plasma through the enFlow fluid warming device. The "lethal triad" of hypothermia, acidosis, and coagulopathy[10] is actively avoided by anticipating hypothermia and actively warming, minimizing acidosis by reestablishing peripheral perfusion, and correcting coagulopathy and fibrinolysis. Because fibrinolysis is common, tranexamic acid 1g IV/IO is administered during the transfusion. The administration of blood products inevitably results in hyperkalemia and hypocalcemia, so 10 mL of 10% calcium chloride is administered after the fourth unit of blood. Early results from a MERT study with an animal model of ballistic injury have shown that the transfusion of early prehospital blood products minimizes the subsequent deterioration in physiology and in particular the level of acute coagulation of trauma.

THE FUTURE

Because of the success of far forward critical care in Afghanistan in improving survival following combat trauma, it will likely remain a component of medical support for future operations. Although operations currently enjoy air superiority, a relative surplus of support helicopters, and minimal ground-to-air threat, these conditions are unlikely to be the case indefinitely. The use of ground transport is a distinct probability, along with prepositioning of critical care assets both for specific operations and for at-risk populations. The secondary transfer of critically injured service members is another likely scenario, either by air or ground, utilizing a prehospital critical care team. The lack of availability of larger support helicopters may change the doctrine to provide a limited "stay-and-play" capability, stabilizing casualties prior to evacuation on smaller airframes or other forms of transport. Conversely, specialized airframes would enable the use of equipment such as rapid infusion systems that is currently available only in Role 3 facilities.

Interventions available to military prehospital practitioners are likely to evolve further. Early use of fibrinogen replacements, proximal control of the aorta via the chest,[9] and endovascular balloon occlusion of the aortic are all future possibilities. The continuing evolution of resuscitation protocols is likely to see a greater breadth of other drugs and novel technologies employed, such as synthetic oxygen-carrying fluids or blood product storage systems. The management of trauma patients in cardiac arrest is an area that requires further work. The success of post-arrest cooling in the civilian arena and work done on emergency preservation in resuscitation (rapid cooling of the brain) may open up yet further improvements in the rate of survival.

As standard operating procedures develop, the type of patient and situation in which primary transfer to specialist facilities such as neurosurgery is feasible will become better established, resulting in decision protocols for clinicians and more consistent care for casualties.

SUMMARY

Medical evacuation from the battlefield has evolved and improved over the past 8 years. Both UK and US assets have played a significant part in the survival of injured military personnel, and the lessons learned must be carried forward into the next operational arena. The UK facility, with its greater capability for advanced resuscitation, has shown benefits for patient survivability; however, the US assets have a crucial place within the battlefield for patient transfer and evacuation, particularly when the tactical situation dictates speed and maneuverability. Each MEDEVAC asset can learn from the others, and the continued working relationship among them will aid in the ongoing improvement of military prehospital casualty care.

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