The critical care air transport program

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Background: **The critical care air transport team program is a component of the U.S. Air Force Aeromedical Evacuation system. A critical care air transport team consists of a critical care physician, critical care nurse, and respiratory therapist along with the supplies and equipment to operate a portable intensive care unit within a cargo aircraft.**

Discussion: **This capability was developed to support rapidly mobile surgical teams with high capability for damage control resuscitation and limited capacity for postresuscitation care. The critical care air transport team permits rapid evacuation of stabilizing casualties to a higher level of care. The aeromedical environment presents important challenges for the delivery of critical care. All equipment must be tested for safety and effectiveness in this environment before use in flight. The team members must integrate the current standards of care with the limitation imposed by stresses of flight on their patient.**

Summary: **The critical care air transport team capability has been used successfully in a range of settings from transport within the United States, to disaster response, to support of casualties in combat. (Crit Care Med 2008; 36[Suppl.]:S370–S376)**

Key Words: patient transport; critical care; military; mechanical ventilation; trauma; casualty; disaster; high altitude; aeromedical

The U.S. military experience at evacuation of casualties by air dates back to World War I. These early efforts led to the organization of an integrated aeromedical evacuation system (AES) by the U.S. Army Air Corps during World War II (1). This system included nurses with specific training for aeromedical evacuation (AE) operating on cargo aircraft returning from the theater of battle. By the 1990s, the AES included command and control functions, trained crews, mobile facilities for staging patients preflight, and extensive logistic support. This system could rapidly deploy, set up, and evacuate large numbers of stable casualties. A limitation of this system was that it lacked the intrinsic capability to manage critically ill casualties, instead relying on medical attendants, supplies, and equipment provided by the sending medical facility. This requirement was a particular challenge for small field hospitals with limited personnel. This was seen in Somalia with the medical response to a surge of combat casualties on October 3 to 4, 1993 (2). In this operation, as casualties accumulated, the most critical could not be immediately evacuated. The requirement to evacuate critically ill patients necessitated the use of critical care personnel from the small field hospital. This was not practical because sending these personnel on a long evacuation flight would seriously degrade their capability to provide care at their field location. After the U.S. military Operation Desert Storm in the Persian Gulf region in 1990, there was a call for the addition of physicians and equipment to AE capable of managing unstable patients in flight (3).

History

During the 1980s and early 1990s, Dr. Paul K. Carlton, Jr, a surgeon, and eventually the Air Force Surgeon General, developed capability for the rapid effective stabilization and transport of casualties (4). This followed his experience at Wiesbaden, Germany, receiving casualties from the Beirut, Lebanon, embassy bombing where the need to transport critically ill patients was illustrated. The search for an effective casualty transport system culminated when Dr Carlton and Dr Joseph C. Farmer, a medical intensivist, launched the critical care air transport team (CCATT) program in 1994. For a 2-yr test phase, this program was based at the Air Force medical centers in San Antonio, TX, and Biloxi, MS. Under the CCATT program, teams were developed consisting of a critical care physician, critical care nurse, and respiratory therapist with supplies and equipment necessary to provide a critical care environment that would move with the patient during evacuation. The concept of the CCATT is to manage stabilizing casualties, those who had undergone initial resuscitation but who remained critically ill. A physician was included on the team to give the patient continuous access to medical decision-making so that therapies could be titrated to the patient's condition, new therapies started if required, and patients could continue progressing toward stability without interruption or setback for transport. After 2 yrs of experience, the program was approved as a component of the AES and teams were established at medical centers and hospitals across the Air Force.

The timing of CCATT development allowed the U.S. military healthcare system to adjust its doctrine in response to changing military strategy after the end of the Cold War. During the Cold War, U.S. forces prepared for large battles in predictable locations supported by robust hospitals with the capacity to hold large

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The views expressed are those of the authors and do not represent the official position of the Department of Defense.

The authors have not disclosed any potential conflicts of interest.

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DOI: 10.1097/CCM.0b013e31817e3143

numbers of casualties until they had completed convalescence and were returned to duty. After the end of the Cold War, the U.S. military became engaged in numerous and diverse activities, including humanitarian and peacekeeping missions as well as combat operations. These tasks often arose quickly, were in unpredictable locations, and in some cases changed locations rapidly. It was no longer possible to establish large-capacity hospitals every time and at every location one was needed. It became necessary to deploy small, high-capability/limited-capacity facilities that could stabilize and evacuate casualties without depleting the limited medical resources at the site of military operations. To accomplish this, military leaders needed to know that even if a casualty was unstable, they could be safely evacuated, and CCATT offered that promise.

Joint En Route Care System

The CCATT program serves as a small, but integral, component of a larger joint-service casualty management system. This system includes contribution from each of the U.S. military services and, in many cases, from coalition partner military medical services. Casualties are evacuated through five levels of care with increasing capability from self- and buddy care with initial management at aid stations close to the point of injury through advanced rehabilitative care at military and Veterans Administration medical centers in the United States.

Casualty evacuation (CASEVAC), a term used by all services, refers to the movement of unregulated casualties by nonmedical units aboard nonmedical vehicles without en route care by medical professionals. The casualty is taken from the point of injury to the most appropriate medical facility. This is typically a level I or II facility, but in a mature operation may be directly to a level III hospital. The CASEVAC mission may involve care under fire, and speed and security are more important than advanced en route care. In the U.S. military, this is overwhelmingly an Army, Marine Corps, or Navy mission. Only rarely is a CCATT involved with CASEVAC.

Medical evacuation (MEDEVAC) refers to a U.S. Army capability involving designated rotary wing aircraft and specially trained enlisted medical crew members. In MEDEVAC, casualties are transported aboard medical helicopters under the care of combat medics with advanced flight training. This capability can be used from the point of injury to a medical facility or between facilities. The constraints of the MEDEVAC environment preclude full application of a CCATT, but on a case-by-case basis, CCATT members have supplemented a MEDEVAC crew.

Aeromedical evacuation refers to the regulated movement of casualties from level II or level III facilities rearward through level V by fixed-wing U.S. Air Force aircraft. The first contact a casualty typically has with the AES is when their attending physician creates a patient movement request, often in coordination with an AE liaison team. A flight nurse/flight surgeon team at an AE control center evaluates this request. At this level, the request is validated, and a discussion ensues to prepare the patient for evacuation. At hubs of the AE system, there are staging facilities that serve as a buffer, allowing casualties to be housed, fed, and prepared for flight at a location from which they can be rapidly loaded when an aircraft becomes available. Aboard the aircraft, an AE crew, consisting of flight nurses and AE medical technicians who have undergone specialized training, manages the patients. The care given by an AE crew is limited by the large number of patients they are tasked to manage and by their lack of specialized training. If a patient requires more care than this basic level, the sending facility is responsible for providing a medical attendant during evacuation. For casualties that are critically ill or injured, the AE system provides the medical attendants in the form of a CCATT. In the regulation process, the casualty evacuation is directed to a facility with available space and the capability that meets the casualty's needs.

The AE function can be categorized as tactical evacuation within a military theater of operations or strategic evacuation between theaters. The most commonly used aircraft for tactical AE is the C-130 Hercules. This aircraft is capable of operating from unimproved air fields and in hostile locations. The C-130 flies at 318 knots at 20,000 feet and has a maximum ceiling of 23,000 feet. The C-130 has the capacity for up to 74 litter patients. The aircraft does not have intrinsic onboard oxygen systems, which mandates that oxygen be carried onboard in a portable liquid oxygen system or as a compressed gas. The electrical system provides 400 Hz AC power through specially configured outlets, limiting its direct usefulness for medical devices. Therefore, the CCATTs must rely on battery power or power provided through an electrical converter. Lighting and environmental control systems are minimal, requiring additional measures for patient warming and visualization of patient care. Lastly, access to patients is limited to 180° (5). The C-17 Globemaster III has the unique role of being an excellent aircraft for both tactical and strategic evacuation. It has a speed of 450 knots at an altitude of 28,000 feet with an unrefueled range of 2,400 nautical miles and unlimited range with aerial refueling. This makes it useful for transoceanic missions. It can also use small, unimproved air fields with runways as short as 3,500 feet and 90 feet wide. The C-17 interior is well lit and the system of litter stanchions provides 360° access to critical patients. The aircraft contains built-in systems that provide medical oxygen at 50 pounds per square inch and 60 Hz AC electric power through standard U.S. outlets. The C-17 can be rapidly configured from use as a cargo aircraft to accommodate 36 litter patients (6, 7).

Critical Care Air Transport Team Capability and Team Function

The CCATT is a three-person medical team consisting of a physician, specializing in critical care, pulmonology, anesthesiology, or emergency medicine; a critical care nurse; and a respiratory therapist. The team is designed to manage up to three high-acuity ventilator patients or up to six lower-acuity stabilizing patients. The team is experienced and current in the care of critically ill or injured patients with multisystem trauma, open/closed head injuries, shock, burns, respiratory failure, multiple organ failure, and other life-threatening complications. The CCATT assumes care of patients being stabilized at a ground-based facility, observes them for stability over a period of typically several hours, and manages the patients through ground and air transportation to reach a hospital with greater capability. The goal is for the care to be seamless with the care delivered by the CCATT as the continuation of a coherent care plan that has been developed along the chain of evacuation.

The decision of what physician specialties to incorporate in the program represents a deliberate balance of factors. The CCATT environment is fundamen-

Table 1. Major curriculum elements for the critical care air transport team initial course

Aeromedical evacuation doctrine	Critical care air transport team supplies and equipment
Altitude physiology	Transport pharmacology
Stresses of flight	Crew resource management
Hypobaric chamber ride	Equipment airworthiness testing/approval
Patient flight physiology	Flightline safety
Acute respiratory failure	Oxygen therapy/systems
Mechanical ventilation	Equipment familiarization
Hemodynamic monitoring	Aircraft loading/configuration
Burn management	Surviving the deployed environment
Transport of medical and trauma patients	Mission management and documentation
Weapons of mass destruction	Training exercises
Infection control	

tally a critical care setting, and it has been demonstrated that intensivist–physician-led teams drive improved patient outcome in the intensive care unit (8). For this reason, CCATT physician recruitment is primarily aimed at physicians who have completed a critical care fellowship. In the U.S. Air Force, like in the civilian medical community, this represents a limited pool of physicians. In addition, the CCATT environment differs in significant ways from a standard intensive care unit. Mission duration ranges from 1 hr to rarely more than 18 hrs; significant physiological flux often occurs requiring frequent titration of care; and the pace of missions can demand rapid assessment and prioritization of care in a medically austere environment. We have learned that the skill sets of anesthesiologists and emergency physicians adapt well to the care of patients in the CCATT environment. The mind set and patient care approach these physicians bring into the development and maintenance of the CCATT program has also been a major benefit. At the time of patient handoff, a physician care plan for the mission is developed that considers the patient's course and anticipated requirements as well as the capability required to meet these needs. If the available CCATT does not meet these needs, the mission is delayed or the team composition is modified. This has infrequently meant the addition of a physician with skills matched to the patient's specific requirements such as a cardiac surgeon for a patient on extracorporeal support.

The team dynamics on a CCATT differ from the normal routine in an intensive care unit. In a hospital, the critical care nurse performs the majority of direct patient care for a given patient, and the usual nurse-to-patient ratio is 1:1 or 1:2. A physician and respiratory therapist generally spend less time at an individual patient's bedside but are responsible for a larger number of patients at a time. Within a CCATT, a degree of cross-training and cross-functionality is essential. A single nurse can cover three to six patients because the physician and respiratory therapist are continuously engaged in the care of the patients and helping with labor-intensive tasks such as tracking and recording physiological trends. In circumstances in which large numbers of critical casualties are anticipated, adding two additional CCATT nurses to the team restores the nurse–patient ratio and extends the useful span of the physician and respiratory therapist. The CCATT function mandates that the team members work and communicate closely. While deployed, the team members live in close quarters and experience the stress of basing and operating in austere conditions, sometimes at extremes of temperature and with exposure to combat. Patient transport missions often occur at night, during which time the transport aircraft is less susceptible to enemy fire, and they often involve significant transmeridian travel, adding shift work sleep disorder and jet lag to the stress on the team. These conditions can magnify otherwise minor personality conflicts and erode the close teamwork and communication that are required for the team to function. When assessing potential CCATT members, it is essential to consider teamwork, communication skills, and personal resilience in addition to education and technical skills.

Critical Care Air Transport Team Selection and Training

Since the inception of the CCATT program in 1994, a formal training pipeline has developed that includes selection, initial training, and skill sustainment. Prospective CCATT members are Air Force members nominated by their commanders to fill positions needed to support deployment requirements. All members go through a CCATT-specific process termed *clinical validation*. In this process, experienced CCATT members from the same crew position (physician, nurse, or respiratory therapist) evaluate the candidate's training and currency. Personnel who are validated undergo initial training at the U.S. Air Force School of Aerospace Medicine in San Antonio, TX, where they complete the 12-day CCATT initial course. The course covers operational concepts, flight physiology to include stresses of flight and flight safety, team equipment, and critical care knowledge as it applies to air and ground transport of the critically injured/ill patient. The curriculum is summarized in Table 1. During the CCATT initial course, students begin developing the unique teamwork required within a CCATT. They receive training from AE crew members and practice in mock-up interiors of the cargo aircraft they will be using, but they do not yet integrate their effort with the remainder of the AE system.

The next step in the training of a new CCATT member is to participate in an exercise that develops the teamwork required to interact the many other components of a fully deployed tactical AE system. This training is offered at Sheppard Air Force Base, TX, in the Aeromedical Evacuation Contingency Operations Training exercise. The other participants in this exercise include the command and control elements, ground staging facilities, and AE crews. A more demanding alternative to this exercise is offered at the Joint Readiness Training Center, Fort Polk, LA.

After this, the CCATT members enter a sustainment phase. The essential element of sustainment is ongoing clinical practice in their critical care-related discipline. When a team is selected for deployment, they must attend the CCATT advanced course in the 120 days before their departure. This 12-day course is offered at the University of Cincinnati Medical Center in a combined program with Air Force and civilian faculty. This course serves three major functions. The deployers refresh their CCATT-specific skills to include training on the team equipment and supplies and review of the flight-related requirements learned in the initial training course and exercise. The course includes 60 to 80 hrs of clinical rotations in the university critical care areas, providing direct care under the supervision of civilian and military faculty. This relatively brief exposure is insufficient

Table 2. Equipment items from the critical care air transport team gear set

Item	Number per Team
Impact 754 volume cycle ventilator	3
Alaris triple-channel infusion pump	3
Propaq encore physiologic monitor with end-tidal CO_2	3
Zoll CCT monitor/defibrillator	1
Impact 326 suction apparatus	3
Casualty blanket	3
Codman ventriculostomy package	1
i-STAT laboratory analyzer	3

Table 3. Critical care air transport team supply list

Emergency resuscitation/airway kits		
Amiodarone		Laryngoscope handle
Sodium bicarbonate		Laryngoscope blades, Miller
Adenosine		Laryngoscope blades, Macintoch
Atropine		Yankauer suction catheter
Calcium chloride		Tracheal suction catheters
Epinephrine		Endotracheal tube stylet
Lidocaine hydrochloride		Endotracheal tubes, cuffed
Magnesium sulfate		End-tidal carbon dioxide detector
Naloxone		Endotracheal tube exchange catheter
Oxymetazoline spray		Eschmann bougeie
Succinylcholine		Wire cutter (dental type)
Vecuronium		Intravenous catheters
Intubating laryngeal mask airway set		Crystalloid infusion solutions
Catheter-needle, 14-gauge 2-inch		Pressure transducers
Kelly forceps		Pressure infusion bags
Magill forceps		Venous guidewire, 0.25-inch diameter
Scissors		Vidacare Ez-Io intraosseous access set
Tongue depressors		Tube thoracostomy kits
Cricothyrotomy kit		Pneumothorax decompression sets
Nasopharyngeal airways		Central venous access kits
Oropharyngeal airways		Cuff manometer
Wright spirometer		Heat-moisture exchangers
Ventilator circuits		
Medication case		
Acetaminophen	Adenosine	Albumin (5%)
Albuterol	Amiodarone	Amoxicillin/clavulanate
Aspirin	Atropine	Calcium chloride
Cefazolin	Ceftriaxone	Clindamycin
Dexamethasone	Diazepam	Digoxin
Diltiazem	Diphenhydramine	Dobutamine
Dopamine	Enoxaparin	Epinephrine
Etomidate	Fentanyl	Flumazenil
Furosemide	Gentamicin	Glucagon
Haloperidol	Heparin	Ipratroprium
Ketorolac	Labetalol	Lamivadine-zidovadine
Levofloxacin	Lidocaine	Magnesium sulfate
Mannitol	Meperidine	Methylprednisolone
Metoclopramide	Metoprolol	Midazolam
Morphine	Naloxone	Nitroglycerin (spray)
Nitroglycerine	Norepinephrine	Oxymetazoline
Phenylephrine	Phenytoin	Piperacillin-tazobactam
Potassium chloride	Procainamide	Promethazine
Propofol	Racemic epinephrine	Sodium bicarbonate
Sodium nitroprusside	Succinylcholine	Vancomycin
Vasopressin	Vecuronium	

to rebuild atrophied skills, but for personnel with adequate currency, the clinical exposure in a range of critical care settings helps standardize practice regarding recent developments in critical care. Perhaps the most important function of this course is intensive exposure to experienced faculty who transmit the most recent lessons learned from current operations. The course includes management of demanding patient scenarios using human patient simulators and CCATT equipment. The culmination of the course is a flying mission, with simulated patients, in which the deployers integrate all of their skills.

Supplies and Equipment

The system for equipping a CCATT represents a balance between the desire to replicate all capability from a hospital-based intensive care unit and the practical limitations of the airlift environment. The CCATT gear set must meet the patient's ongoing care requirements. This includes physiological monitoring of the electrocardiograph, invasive and noninvasive vascular pressures, oxyhemoglobin saturation, end-tidal carbon dioxide, intracranial pressure, and body temperature. The team must be able to deliver infusion therapy of fluids and medications, provide mechanical ventilation across a range of settings, and perform laboratory analysis of blood. The gear set must also support the rapid response to emergencies that can occur in the intensive care unit. These emergencies include airway compromise, loss of secure airway, loss of vascular access, pneumothorax, and other causes of major decompensation. The major equipment items and supplies assembled to meet these challenges are listed in Table 2 and Table 3, respectively.

The CCATT gear set, consisting of all the supplies and equipment, must be man-portable, able to be set up and taken down rapidly as well as safe and effective in the aeromedical environment. The most fundamental item is a standard-sized litter made of canvas or nylon with wooden or metal poles, which mounts inside the aircraft on stanchions. The CCATTs use a metal bracket that clamps to the litter poles, straddling the patient, with the ventilator, monitor, infusion pump, and suction apparatus secured to its surface. For transport between missions, this gear is packaged in backpacks designed for CCATT. The packing system is designed to be scalable. The full set is sized to allow the team to function for 5 typical days without resupply, but in many circumstances, carrying all of this is not practical so the set was designed such that a subset can be used with less quantity but no loss in capability. The backpacks are designed to hang along the side of the aircraft fuselage and unroll to allow access to items secured inside zippered pockets.

The equipment must meet stringent criteria of airworthiness and interoperability before it can be used in CCATT. The major testing hurdles before approval for use in flight include interface with the aircraft oxygen and electrical systems; assessment of how the device functions across the cabin altitude range of a typical mission (sea level to 8,000 feet) and with rapid decompression to the flying altitude; whether the device produces electromagnetic emissions that interfere with aircraft systems; whether electromagnetic emissions from the aircraft interfere with device function; and effect of vibration on the device. Another important consideration is how the equipment interfaces with that used by the facilities referring patients to CCATT. The goal is to eliminate the necessity of changing patient-applied support devices when care is transferred to the CCATT. These devices include intravenous drip sets, pressure transducers, oximeter probes, and monitor cables. These device swapouts slow down care, waste supplies that may be limited, and introduce opportunity for error. Meeting these requirements of safe, effective, and interoperable function in the CCATT environment represents a major hurdle to rapidly upgrading the equipment items, but the consequences of not meeting these requirements is an unacceptable risk of failure.

Critical Care Air Transport Team Program Organization

The U.S. Air Force's Air Mobility Command has oversight of all aspects of the AES to include CCATT. The CCATT program oversight specifically falls under the office of the Air Mobility Command Surgeon at Scott Air Force Base, IL, which ensures that development of the program integrates successfully with development in the remainder of the AES. This oversight is exercised through multiple mechanisms to include the CCATT working group, which includes headquarters staff along with experienced CCATT members. This body meets regularly to assess the state of the program, address challenges that have arisen, and recommend a future course of development. There is also a CCATT pilot unit at the Air Force's oldest and most active CCATT unit at Wilford Hall Medical Center in San Antonio, TX. The pilot unit is an information resource for other units, runs the CCATT performance improvement program, and works on many of the details of maintaining and updating the equipment set. The U.S. Air Force maintains a total of 50 teams across its medical centers, hospitals, and in the Air Force Reserve. These teams do not perform the CCATT mission during daily operations, but rather prepare for possible deployment for 4 to 6 mos at 20-mo intervals.

Critical Care Air Transport Team Operations

Clinical and Physiological Aspects of Critical Care Air Transport. The practice of CCATT is based on the current standard of practice in critical care medicine, nursing, and respiratory therapy. The CCATT program strives to make optimal use of clinical practice guidelines as a starting point for planning and delivering care, but not as a substitute for the clinical judgment of the individual team members. As the CCATT program was being set up in 1994, recently published multisociety consensus guidelines for the transfer of critically ill patients were integrated into the developing CCATT practice (9). These guidelines were updated in 2004 (10) and the updated recommendations have again been incorporated into CCATT practice where appropriate. As mentioned, the CCATT advanced course represents an opportunity to ensure that all members have updated their practice to current best evidence standards before their deployment.

The CCATT practice must be modified from the civilian standard based on the unique characteristics of combat casualties. In current operations, the casualty mix managed by the CCATT program is weighted toward complex polytrauma patients, often with multiple severe extremity wounds, burns, blast injury, and penetrating skull trauma. The CCATT members function as a component of the U.S. military Joint Theater Trauma System, described in this supplement (11). The leaders of this trauma system have developed clinical practice guidelines that integrate the best evidence-based practices from civilian critical care with lessons learned from managing complex combat–trauma casualties. These lessons are primarily gleaned from analysis of a trauma registry database and are refined through a weekly system-wide case management conference with participants from forward surgical facilities up to and including large medical facilities in the United States that are receiving casualties. The conference organizers track and analyze all occurrences that fall outside determined parameters. The deployed CCATT members receive casualties whose care is proceeding according to the Joint Theater Trauma System guidelines, continue this approach as appropriate in their judgment, and hand off the casualties to another hospital that uses the same guidelines. An example of refinement in care that has been incorporated in CCATT practice is the extensive use of vacuum-assisted closure of complex wounds initiated in the field (12) and now continued in flight.

The practice of critical care in flight incorporates practices from civilian critical care and from the care of casualties on the ground, but must adapt all of these to the unique environment of in-flight care. The major stresses of long-range flight for the patient are the hypobaric environment causing gas expansion; decreased partial pressure of oxygen; severely reduced relative humidity; acceleration and position change during takeoff, landing, and maneuvering; and vibration. The effect of these factors on mechanical ventilation has been reviewed (13). Critical planning factors include ensuring sufficient oxygen supplies for the duration of the mission plus a safety factor for in-transit delays. It is also essential to have a plan for preventing gas expansion in a tracheal tube cuff such as replacing the air with normal saline solution or frequently monitoring and adjusting cuff pressure with changes in cabin altitude. We have not experienced significant difficulty from patients with severe acute respiratory distress syndrome (ARDS) decompensating during flight. The mechanisms impacting this are not yet fully understood, but an experimental model has demonstrated the effectiveness of positive end-expiratory pressure at maintaining oxygenation in ARDS at a typical cabin altitude for CCATT missions (14). In accordance with current standards, CCATTs are taught to use positive end-expiratory pressure when managing patients with acute lung injury/ARDS.

The first major decision faced by the CCATT is the decision to evacuate. The transfer must be in the patient's best interest, must not be financially motivated, and must be agreed to by the patient or a surrogate decision-maker after discussing the risks, benefits, and alternatives. The primary indication for a CCATT transport is to move the patient from a setting in which resources are insufficient for the patient's requirements to a setting that meets these needs. In the settings of combat or a disaster, this decision must consider the likelihood that resources at the sending facility will be overwhelmed by a future influx of casualties.

Once the team is committed to move a patient, adequate patient preparation is essential. The team must anticipate complications that can occur in transit and take decisive steps to prevent them. This step is common to all patient transfers whether within a hospital for a procedure or for a transoceanic flight. A recent review discussed this step in detail and provided a sample preflight checklist (15). It is easier and safer to perform needed procedures on the ground preflight than within the cabin of an aircraft in flight. Major pitfalls to avoid are anatomic trapped gas that will expand at altitude; an unsecured airway in a patient with inhalation injury, a fluctuating mental status, or worsening pulmonary status; hemorrhage that has not been controlled; and at-risk regions for compartment syndrome, such as injured extremities, a closed abdomen, or the skull, which have not been addressed surgically preflight. Injured extremities, in particular, are at risk for worsened edema on exposure to a hypobaric environment. In addition to adequate preflight fasciotomy when indicated, if a cast is used, it must have bivalve cuts made to allow for expansion of the extremity at altitude.

Peacetime Operations

In the early years of the CCATT program, a major source of experience was the transport of patients within the continental United States and from the Caribbean and Central or South America. The indication for these transports was generally evacuation from a medically austere location or transfer to a location with highly specialized care such as organ transplant, specialized burn care, or advanced ventilator support. After the entry of the United States into war in 2001, the focus on CCATT shifted to deployed operations and the home station mission was largely turned over to civilian air transport services.

Deployed Operations

The first major employment of CCATT for casualty movement was in support of the coalition peacekeeping operation in Bosnia beginning in December 1995 (16). For this operation, teams from units in the United States were temporarily based in Germany. While deployed, these teams were often used for additional missions such as transport of military healthcare beneficiaries within Europe, the response to a terrorist bombing at an air base in Saudi Arabia, and the evacuation of personnel from the U.S. embassy in Liberia. As the CCATT test program was completed and the concept accepted, Germany-based teams were developed to take over this mission. Among other successes, these teams responded to the terrorist bombing of the USS Cole in Yemen in October 2000, safely transporting critically injured casualties to Germany (4).

A major test of the CCATT program occurred in 2001 to 2002 when the United States entered combat operations in Afghanistan. The U.S. military had no existing medical infrastructure in this country to manage the combat casualties that were generated. As had been planned, small surgical facilities were set up in proximity to combat to provide lifesaving damage control resuscitation. The limited capacity of these facilities, and the imperative that they be prepared to receive further casualties, drove the requirement for rapid evacuation of stabilizing casualties. The CCATTs operated out of these forward locations, transporting casualties up the evacuation chain to higher levels of care. As combat operations continued in Afghanistan, and began in Iraq where the casualty flow was much higher, the CCATT program needed to expand and sustain itself with no loss in quality. In 2004, an analysis of the outcome of combat casualties found a 90% survival for war wounds, representing a marked improvement in survival over previous major wars (17). Multiple factors contributed to this success, including improved personal protection, rapid access to high-quality lifesaving surgery, and rapid transport of casualties to a higher level of care. Current data do not support an analysis of the relative contribution of these factors; however, the most vulnerable casualties were managed by CCATTs during their evacuation, and casualty survival would not have reached this level had the CCATT program not provided quality care. As of the end of 2007, over 2000 casualty evacuations have been performed in Iraq and Afghanistan by CCATTs (U.S. Transportation Command Data).

Disaster Response

Since its inception, the CCATT program has participated in the medical response to natural and man-made disasters. An early such mission occurred in 1997 when teams responded from Texas to a Boeing 747 airliner crash on Guam. A combined CCATT and burn transport team managed four critically burned survivors during 21 hrs of in-flight care, delivering them safely to the U.S. Army Burn Unit in San Antonio, TX (18). A more recent example was the participation of CCATTs in the response to Hurricane Katrina on the U.S. Gulf Coast in 2005 (Todd E. Carter, MD, personal experience). Critically ill and injured victims of the storm were accumulated at the New Orleans Airport and then transferred out of the disaster area on Air Force cargo aircraft while under the care of CCATTs.

The CCATT program has proven successful in decompressing a disaster area of the casualties who are both most vulnerable and who consume the greatest amount of resources and caregiver attention. The CCATT capability is rapidly deployable, can operate on the ground in a disaster area to augment local resources, and can manage casualties during evacuation. An inherent efficiency of the U.S. Air Force AES, including CCATT, in disaster response is that cargo aircraft bringing relief supplies into the disaster area can depart with a large number of casualties, even those who are unstable. Multiple authors have proposed that this model be incorporated in the development of future disaster response capability (19–22).

International Engagement

The U.S. Air Force has produced a portable 5-day course for international military medical services interested in developing or enhancing their capability for critical care transport. This course has been given in Chile, Mexico, Colombia, Bangladesh, Turkey, Morocco, and the Republic of Georgia (William Beninati, MD, and Todd E. Carter, MD, personal experience). The focus in this brief course is on disaster response within that nation and their region of the world. The course trains experienced host nation medical personnel in one approach that has been successful. Training materials are left behind to encourage the course attendees to continue training in their nation with or without ongoing involvement of the U.S. Air Force. The course adopts best practices from the various nations who host the course and shares them across other nations, aiming to foster interoperability and cooperation in the event that we end up working together in the response to a disaster.

Future Directions

A registry database is currently in development for patients being cared for by CCATT. The objective of this is to support a performance improvement program seeking to identify suboptimal outcomes and the factors that contribute to them. This database is designed to integrate with the existing Joint Theater Trauma Registry to leverage the large amount of data that is already collected on these patients. The patient care documentation for CCATT currently occurs on paper using a simplified critical care flowsheet and additional progress notes as required. This limits the portability of this data to support patient care, future disability determination for combat casualties, and the performance improvement program. For these reasons, a CCATT electronic medical record is also in development.

The current major CCATT equipment items are more than 10 yrs old. This equipment has proven reliable and safe but does not represent the best technology available. A major effort is underway to perform a technology catch-up to enhance the performance and safety. Among the options being considered is an integrated platform with a physiological monitor, ventilator, infusion pump, and possibly other items, all connected to a central controller. Automatic data logging of information from these items would enhance accurate recordkeeping and potentially permit closed-loop control and telemedicine applications.

The next major advance in the CCATT practice is to more tightly integrate training, equipment, documentation, procedures, and performance improvement across all critical care settings beginning immediately after initial resuscitation of the casualty and continuing through rehabilitative care. This effort across the military services will eliminate undesired variability in care and support a uniform high standard.

CONCLUSION

The CCATT capability was developed to provide the U.S. Air Force AES with the intrinsic capability to transport stabilizing critically ill and injured casualties. This permits surgical teams to remain small and mobile enough to keep pace with the military operations they support and still provide advanced resuscitation, because they are relieved of the resource-intensive burden of postresuscitation care. Since the program's inception in 1994, the CCATT program has performed superbly in support of peacekeeping operations and sustained this performance in support of sustained combat operations lasting for more than 6 yrs and producing over 2,000 critical casualties. This capability has also performed well in disaster response operations, helping to decompress the disaster area of the casualties who are both most vulnerable and who consume the greatest quantity of resources. Future development in the CCATT program includes refining the care delivered through enhanced equipment and a performance-improvement program based on an emerging robust registry database. This concept is also being developed as a U.S. civilian and international model for a key component of disaster relief operations.

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