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The critical care air transport experience

Peter G. Crawley[1]

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Abstract There have been over 8000 documented patients transported by US Air Force critical care air transport teams (CCATT) since the beginning of US military involvement in Iraq and Afghanistan (Ingalls et al. in JAMA 149:807–13, 2014). As part of the joint service, integrated and multi-tiered aeromedical evacuation system (AES), critically ill or injured service members are transported by CCATT on tactical (short range, within a theatre of operations) and strategic (long range, between theatres of operation) missions. Within the AE system, patients move through five echelons of care, beginning with care at the point of injury and culminating at major military medical centers in the United States. Patients with critical injuries sustained during support of Operation Iraqi Freedom (OIF) or Operation Enduring Freedom (OEF) are first transported to Landstuhl Regional Medical Center (LRMC) in Germany where they are further stabilized for transport back to US facilities. Flight times between evacuation hospitals within the theatre of operations and LRMC can be as long as nine hours. During transport, CCATT monitor patients and continue ongoing resuscitation and treatment plans. Teams are equipped and prepared to intervene should emergent care be required. Critical patients transported to LRMC will often undergo further surgery and frequently require ICU level care with CCATT for transport from LRMC back to the USA. During the peak of conflicts in Iraq and Afghanistan, aeromedical evacuation of critical patients from the point of injury back to the US typically took 2–4 days (Dorlac et al. in J Trauma 66:S164–71, 2009). The paradigm of transporting "stabilizing" patients, even those with severe traumatic injuries over transcontinental distances and often just hours after initial damage control surgery, is supported by a 0.02 % en route mortality rate and a 98 % survival rate among individuals wounded in OIF/OEF that are transported back to LRMC (Ingalls et al. in JAMA 149:807–13, 2014). The long-range transport of critical patients in the austere environment of a military aircraft creates unique challenges for the transport team and is a vital part of the evolving globally mobile medical support apparatus. This article describes both the role of Air Force CCATT within the context of the integrated military AES and the CCATT mission experience in the deployed environment. The role of specialized transport teams and the expanding role of CCATT in a variety of noncombat operations will also be discussed.

Keywords Critical care air transport team (CCATT) · Aeromedical evacuation · Echelons of combat care · Specialized military transport teams

Introduction

Although the romantic notion that French "aeronauts" used hot air balloons in the Franco-Prussian war to ferry wounded soldiers out of Paris while the city was under siege in 1870 has largely been discredited [1, 2], the use of aircraft to rapidly transit injured patients to higher echelons of care has been a significant military contribution to healthcare. In the USA, the first "air ambulances" were utilized to evacuate military personnel in World War I when the open rear cockpit of a Curtiss JN-4, known as "Jenny," was modified to fit a single standard Army stretcher [3]. An integrated aeromedical evacuation (AE) system was established by the Army Air Core in WWII. The system began with nurses that received specialized training in AE on

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✉ Peter G. Crawley
peter.crawley@us.af.mil

1 Pulmonary Department, Wilford Hall Ambulatory Surgical Center, 2200 Bergquist Dr, San Antonio, TX 78236, USA

cargo aircraft and evolved to include command and control functions, trained crews, and extensive logistic support and was designed to transport stable patients [4]. Medical transports during the Korean and Vietnam wars were performed in helicopters primarily to evacuate casualties from the immediate battlefield or to hospital ships after initial treatment in field hospitals [5]. The image of the medical evacuation helicopter during the Korean War in the TV series MASH, or “dustoff” helicopters from Viet Nam era news reels, remains one of the most powerful images in US military medicine. Although there were very significant advances in aeromedical evacuation during these conflicts that translated into improved civilian medical transport systems [5, 6, 7], there was no experience with long-range transports of critical patients.

Within the military AE system, prior to the development of specialized CCAT teams, it was the responsibility of the medical treatment facility (MTF) to supply the appropriate personnel, equipment, and medications to care for critical patients in transit. Aeromedical evacuation doctrine was based upon cold war era assumptions that the US military would be involved in large-scale, nation against nation conflicts supported by high capacity hospitals designed for long-term convalescence. In this scenario, transport of critical patients would be relatively rare. When it was necessary, large MTFs could provide personnel and equipment without significantly degrading capabilities. In the current era of asymmetric warfare, forward medical facilities are smaller, modular, and mobile [8]. Critical patients that have undergone immediate stabilizing interventions at a forward facility need to be rapidly transported rearward in order to make room for the next wave of casualties. Smaller medical facilities do not have the capacity to treat patients until they are considered stable for evacuation, and it is not feasible to send limited supplies and personnel with a patient. The “Black Hawk Down” engagement in Somalia in 1993 highlighted the need for self-sufficient critical care transport capabilities and served as a catalyst for change in the AE system [4, 9].

The logistics of providing intensive care to postoperative patients in far forward theatres of operation are very difficult [10]. The CCATT concept was developed as a possible solution [11]. The development of self-sufficient specialized teams that can augment AE capabilities by treating critical patients allowed patients to be moved rearward instead of bringing greater ICU capabilities forward. In this way, smaller, mobile facilities could be rapidly offloaded in preparation for more casualties. In 1994, under the guidance of Lt. Gen. (Dr.) Paul K. Carlton, a former Air Force Surgeon General, a group of key Air Force surgeons and critical care physicians came together to develop the concept of CCATT [4, 12]. Proof of concept was established during the Bosnian peacekeeping operations and subsequent humanitarian missions, including the crash of a US airline Boeing 707 cargo plane in Ecuador in 1995 (http://aviation-safety.net). In 1996, CCATT was formally adopted into the USAF AES and a “pilot unit” was established at the 59th Medical Wing at Lackland Air Force Base in San Antonio. The pilot unit is responsible for performance improvement, innovation, and equipment supply for CCATT across the Air Force. In 2004, the pilot unit began collecting and collating CCATT mission reports from Operation Iraqi Freedom and Operation Enduring Freedom. This data is part of the Department of Defense Trauma Registry (formerly known as the Joint Theatre Trauma Registry, 13, 14) and is used to establish the Joint Trauma System Clinical Practice Guidelines (CPGs) published on the US Army Institute of Surgical Research website (http://www.usaisr.amedd.army.mil). Since its inception in 1996, CCATT has been used in operations other than war, including humanitarian missions and in support of natural disasters [15]. In 2010, the CCATT mission expanded into the Pacific. Critical transports in this region often originate in remote islands with limited medical resources and involve distances that cover nearly one half of the world’s surface area, introducing a unique set of challenges to the CCATT community.

The role of CCATT within the aeromedical evacuation system

Military aeromedical evacuation is a joint service, integrated system that begins at the point of injury and continues through five echelons of care culminating in large, specialized military treatment centers in the United States [3]. The “forward” aeromedical evacuation (FAME) system is part of the first echelon of care which includes self-aid and buddy care as well as interventions by combat medics from each of the branches of service: Army special forces medics, independent duty Navy corpsmen, and Air Force pararescuemen [16]. Combat medics have specialized training in trauma resuscitation and airway management and generally perform transports by helicopter. The prehospital period, often referred to as the “golden hour” in civilian trauma literature, has been the topic of a recent review [17]. Echelon I care may also include a small, forward located battalion aid station or US Marine Corp shock trauma platoon [18, 19] where there are emergency medical capabilities but no surgical capabilities. Echelon II care includes mobile medical facilities that are forward located and are typically staffed by trauma and orthopedic surgeons [20]. Echelon II facilities perform immediate life-saving “damage control” surgery and are equipped with basic laboratory and X-ray capabilities.

Echelon III medical facilities provide comprehensive surgical subspecialties including neurosurgery and ophthalmology and have robust intensive care medical capabilities. This echelon of care represents the highest level of medical care within the theatre of operations. The medical facility at each echelon of care is referred to as the corresponding level of care facility. For instance, an echelon III medical facility like the hospital located at Bagram Air Base in Afghanistan is referred to as a level 3 facility [21].

Historically, for combat operations in Iraq and Afghanistan, there is a 98 % survivor rate for patients who survive to be transported out of an echelon III facility [22••]. The hospital at Bagram Air Base is an echelon III facility where many of the CCATT strategic transport missions originate. During combat operations in Iraq, the hospital at Balad Air Base served as the primary Echelon III facility for evacuation out of the combat zone. CCATT performs tactical transports between echelon II and III facilities within the combat zone and strategic transports out of the combat zones. Echelon IV medical facilities are regional medical facilities located outside the combat zone but not in the continental US, like Landstuhl Regional Medical Center. Finally, echelon V facilities are trauma centers located in the United States with reconstructive and rehabilitation capabilities. If necessary, patients can be moved through all echelons of care within a 24-48 hour period. The role of CCATT within the larger scheme Aeromedical Evauation is shown in Fig. 1.

CCAT team composition and equipment

Critical care air transport teams are three-person teams comprised of a respiratory therapist, a critical care nurse and a physician experienced in critical care medicine. In the Air Force, the CCATT physician is primarily selected from among the subspecialties of anesthesia, emergency medicine, or pulmonary/critical care medicine, although other medical subspecialists and general internal medicine physicians are also utilized depending on critical care experience [23, 24]. A single CCATT has the capability of transporting up to three patients on mechanical ventilators and a total of six critical patients. Each team member is trained on all equipment to provide redundancy in flight. If one team member is incapacitated in flight, the remaining members can still care for patients. CCATT medical gear is portable and battery operated, consisting of two backpacks (47 lbs each), nine equipment and medical supply bags, and one drug case. There are three full sets of patient equipment bags that each contain a Uni-Vent Eagle 731 portable ventilator (Impact Instrumentation Inc., West Caldwell NJ or LTV 1000/1200, Pulmonetics Systems, Minneapolis MN), a cardiac/physiologic monitor (WelchAllyn Propaq, Skaneateles Falls, NY), a computerized intravenous triple channel infusion pump (Alaris IVAC, San Diego, CA), and a continuous suction unit (Impact Instrumentation Inc., West Caldwell NJ). In addition, CCATT carries a Zoll defibrillator, intubation and difficult

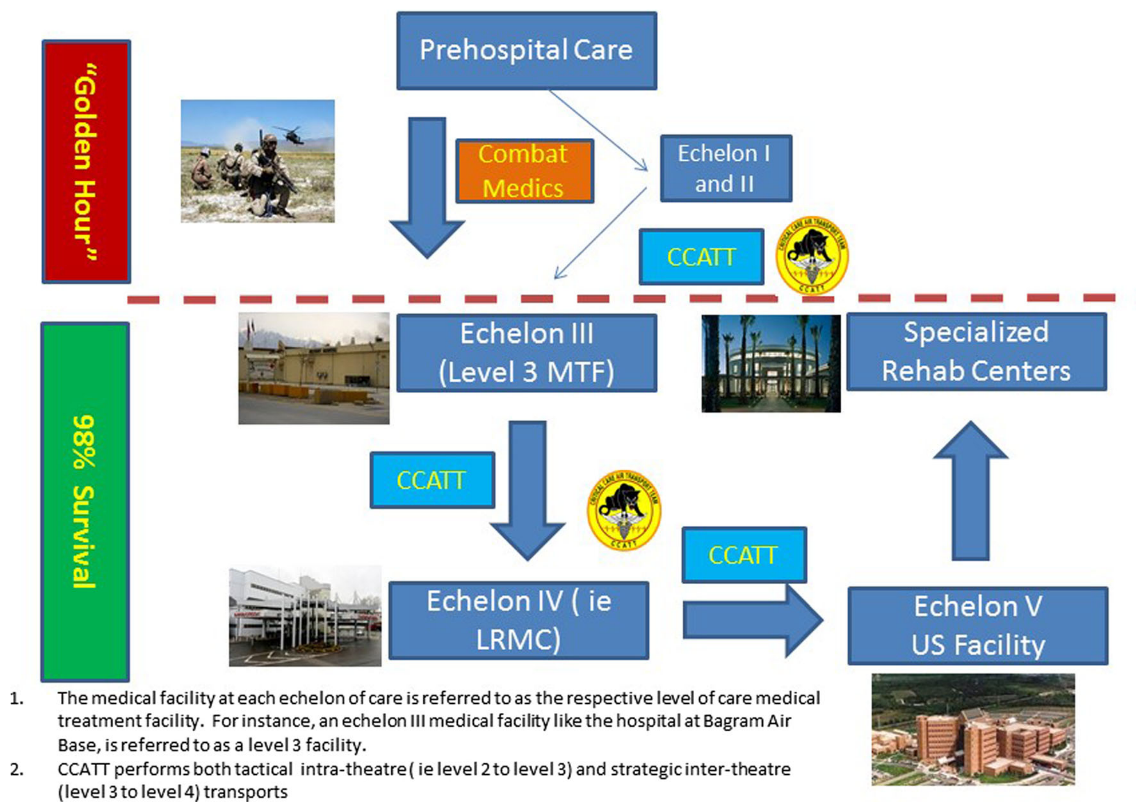

Fig. 1 CCATT and the Echelons of Combat Care. The *red dashed line* represents the separation between combat care occurring before reaching the highest level of care within the combat zone (level 3 facility) and higher levels of care. Most of the pre-hospital transport of casualties is accomplished by specialized combat medics from all three service branches. CCATT will perform intratheatre, tactical transports, from level 2 MTFs to level 3. In addition, CCATT will perform longer range transports from a level 3 evacuation facility (i.e., Bagram) to LRMC and from LRMC back to the United States. Points of CCATT involvement in the larger AE system are represented by a yellow CCATT patch with the black "CAT" insignia. See text for more details describing the Echelons of Combat Care

airway equipment including a Glidescope Ranger (Verathon Inc., Bothell, WA), point of care arterial blood gas kits, procedure kits for chest tubes, central lines and arterial lines, and a medication supply with basic ICU and ACLS medications. The entire equipment package weighs 900 lbs and is transported using multiple litters placed in stanchions on the aircraft.

CCATT physician training

There are currently over 90 CCATT teams within the Air Force divided between active duty and reserve components. The US Air Mobility Command (AMC) at Scott Air Force Base in Illinois has oversight over all aeromedical evacuation and is responsible for training and maintenance of CCATT. Physicians with backgrounds in critical care, anesthesia, emergency medicine, or occasionally general internal medicine or cardiology can be selected for CCATT. Physicians must complete a 12-day CCATT initial course at the US Air Force School of Aerospace Medicine at Wright Patterson Air Force Base in Ohio. The course introduces the equipment used in transport and focuses on the unique aspects of altitude physiology applied to critical care in flight. Following the introductory course, there is an advanced course at the Center for Sustainment of Trauma and Readiness Skills (C-STARS), at University Hospital in Cincinnati OH. The 14-day advanced course has both a didactic and clinical skills component. The didactic portion focuses on the management of trauma, while the clinical component is simulator based in an environment that mimics the flight environment. Teams practice working through a series of clinical scenarios based on actual CCATT patients. The sessions are recorded and teams have the opportunity to review the effectiveness of mission planning, communication, and clinical decision-making. The course concludes with a field exercise that simulates a CCATT mission. Teams are given PMRs for a number of simulated patients and are expected to carry out a complete simulated mission. During the flight, teams are again expected to problem solve a variety of clinical scenarios. Physicians maintain currency for CCATT by attending the C-STARS course every 2–3 years. In addition, there are local CCATT training exercises that ensure team members maintain familiarity and stay current with changes or additions to the equipment.

The CCATT mission in Iraq and Afghanistan

Within the joint AE system, when a patient is initially identified as requiring CCATT at a forward located medical facility, the bedside physician completes a patient movement request (PMR). The PMR form includes patient demographics, mechanism and time and extent of injuries (if known), interventions and blood products received, and data about current clinical status. The patient is also entered into the Transportation Command (TRANSCOM) Regulating and Command and Control Evacuation System (TRAC2ES). This system provides information on incoming and outgoing flights and allows in-transit global visibility of all patient movements. Because AE relies on aircraft of opportunity, coordination of available aircraft with patient movement requests is essential for timely evacuation of patients. The PMR is sent to the regional theatre Patient Movement Requirements Center (PMRC). This facility is responsible for regulating and coordinating all patient movements originating in the theatre of operations. The Joint Patient Movement Requirements Center (JPMRC) at Al Udeid Air Base in Qatar is responsible for patient movements in Iraq and Afghanistan. At JPMRC, there is a second level of review of transport requests. If further questions about the status of the patient arise, JPMRC will communicate directly with the physician at the originating facility. Once the mission requirements for CCATT are confirmed by JPMRC, the local aeromedical evacuation command tasked with the mission is notified. CCATT is an asset of the AE system and augments a five-person AE crew that cares for all noncritical patients that may also be transported on the mission. The AE crew is responsible for configuring the aircraft for medical transport missions and for the safety of all patients and CCATT members in the aircraft. The AE crew is comprised of two flight nurses and three AE technicians. The choice of aircraft depends on availability and mission requirements. The C-130 Hercules is a four-engine turboprop airplane that can land and take off in relatively short, unpaved runways and is the primary aircraft used for intra-theatre tactical CCATT missions. The C-17 Globemaster and KC-135 Strato-tanker are used for strategic patient movements out of the theatre back to Germany. The C-17 is a dual-purpose aircraft designed for cargo and troop transport and for aeromedical evacuations. It has an onboard oxygen supply and can be configured to transport up to 36 litter and 54 ambulatory patients and attendants [25•].

Once the local AE command has been notified of a mission with a CCATT requirement, the "on call" CCATT and AE crews are alerted, typically 4–6 h prior to the scheduled takeoff time. If the patient is colocated with the CCATT team, the team will assess the patient at bedside. If the CCATT team and patient are not at the same site, then the team will rely on the limited amount of information in the PMR prior to take off with an understanding that the clinical situation may be dramatically different on arrival. For instance, if the CCATT team is in Germany and the patient is in Afghanistan, the team may arrive after an 8 h flight to find that the patients they had been tasked to transport had already been evacuated by another CCATT. Teams must be prepared for some uncertainty and maintain a high degree of flexibility based on operational requirements. In general, CCATT deployed to bases in Iraq or Afghanistan have been tasked with intra-theatre, tactical missions between more forward medical facilities to larger theatre hospitals, and occasionally also perform inter-theatre missions transporting patients back to Germany. CCATT deployed to Germany have historically been tasked to transport patients out of theatre back to Germany and also to transport patients from Germany back to the USA. CCATT located in Germany that are tasked for transport of a patient in Afghanistan will "dead head" from Germany with their equipment, often in an aircraft that is fully loaded with pallets of supplies for downrange bases. Upon arrival at the downrange airbase, CCATT is transported with their equipment to the medical facility. Any cargo is off-loaded and the plane is reconfigured for medical transport by the AE crew. CCATT typically will have a 2–3-h window on the ground prior to the scheduled return flight. During this time, patients are placed on the CCATT monitors, IV pumps and, if mechanical ventilation is required, transferred to the CCATT portable ventilator. The changeover of equipment from ICU monitors, pumps, and ventilators to the CCATT transport equipment typically requires 30–45 min depending on patient complexity and team experience. During this time, the physician will evaluate the CCATT patients, assess the risks and benefits of transport, and determine if any additional interventions need to be performed prior to flight. Particularly for long-range flights, when clinical status can change significantly, there are a number of important considerations that should be addressed prior to take off.

1. Patient oxygenation: 10 % of combat casualties in Iraq and Afghanistan develop severe pulmonary injury, commonly blast injuries [26]. Although body armor is protective against secondary lung injury from projectiles, it is not necessarily protective against primary blast injuries [27]. One in six of blast injury patients is evacuated with moderate-to-severe acute respiratory distress syndrome (ARDS) [28, 29]. In the author's experience, the transition to a portable ventilator will often require increased FiO_2 and sedation. Differences in set-to-delivered FiO_2 accuracy and increased patient-ventilator dyssynchrony may contribute to increased work of breathing and desaturations during the transition to portable ventilators [30]. It is not uncommon to require an additional 10 % FiO_2 to maintain identical oxygen saturations immediately after transitioning to a portable ventilator. In addition, the cabin altitude of military flights (and civilian flights) is normally maintained at 8000 ft. The decrease in barometric pressure at altitude will require an increase in the FiO_2 delivered to maintain the equivalent FiO_2 being delivered at takeoff. For instance, if the FiO_2 is 70 % at takeoff (assuming take off is at sea level), a FiO_2 of 98 % will be required at 8000 ft. The relationship between altitude and FiO2 requirements is shown in the Table 1. The empty rectangles represent altitudes above which the FiO_2 set at ground level cannot be achieved. For instance, at 8000 ft, 55 % FiO_2 will be required to equal 40 % FiO_2 at sea level.

   In addition to differences in oxygen requirements on portable ventilators and the effect of decreased barometric pressure of oxygenation, secretions are mobilized during takeoff and periods of turbulence. Particularly, if there have been problems with oxygenation from mucous plugging on the ground prior to take off, worsening oxygenation during takeoff and during turbulence can be anticipated. There is also significantly less humidity at altitude and secretions can dry out and be much more difficult to mobilize with suctioning. For this reason, a heat and moisture exchanger (HME) is required on all ventilated patients. Although, there are no absolute limits that define what oxygenation levels are unsafe, current CCATT clinical practice guidelines on mechanical ventilation can be found on the USAISR website and suggest that if FiO_2 is at or above 70 % and PEEP at or above 14 cm, then the risks and benefits of transport should be carefully considered.
2. Evaluate for signs of active bleeding: Because of the long flight times and limited surgical divert capabilities, all occult bleeding must be addressed prior to transport. Up to 65 % of all patients being transported via CCATT out of the OIF/OEF have suffered traumatic injuries often caused by improvised explosive devices. Multi-trauma patients requiring damage control surgery and massive resuscitation can still safely be transported by CCATT even within hours of surgery. However, because internal bleeding cannot be addressed in flight, if there are clinical

Table 1 Altitude and FiO_2 requirements

Altitude (ft)	Barometric pressure (mmHg)	Gas volume % expansion	FiO_2 required to maintain equivalent FiO_2 at sea level							
Sea level	760	100	0.21	0.30	0.40	0.50	0.60	0.70	0.80	0.90
2000	707	107	0.23	0.32	0.43	0.54	0.65	0.76	0.86	0.97
4000	656	116	0.24	0.35	0.47	0.58	0.70	0.82	0.94	
6000	609	125	0.27	0.38	0.51	0.63	0.76	0.89		
8000	564	135	0.29	0.41	0.55	0.69	0.83	0.96		
10,000	523	145	0.31	0.45	0.60	0.75	0.90			
12,000	483	157	0.34	0.49	0.65	0.81	0.98			

concerns about ongoing bleeding prior to take off, communication with the surgeons should ensue to determine whether further imaging or surgical evaluation is indicated. Additional blood products are transported with patients when there is ongoing resuscitation.

3. Determination of air in closed anatomic compartments: As shown in Table 1, air trapped in closed compartments will expand with increasing altitude. At 8000 ft, the volume of air will be 1.5 times greater than it was at sea level. Pneumocephaly or air trapped anywhere within the eye requires further evaluation. Additionally, a chest tube should be placed for all pneumothoraces prior to flight even if they are small enough to warrant observation on the ground. Small air bubbles trapped within the IV tubing on the ground can expand at altitude and cause the IV pump to alarm and disrupt infusing medications. Every attempt should be made to remove air within the IV tubing prior to transport to avoid unintended disruptions of continuously infusing medications.
4. Evaluate for compartment syndrome: In multi-trauma patients requiring massive resuscitation, compartment syndrome of the extremities is common [31, 32]. Tissue edema reaches a maximum at 1–2 days post-injury which is often the window for transport [1]. High altitude has been shown not to contribute to compartment syndrome [33]. However, because compartment syndrome is associated with significant morbidity and mortality, prophylactic fasciotomy is often indicated. Abdominal compartment syndrome is a potentially lethal complication of a variety of combat injuries and massive resuscitation. If abdominal compartment syndrome is suspected, a decompressive laparotomy should be performed. If not addressed prior to transport, nonreversible multi-organ system failure can ensue within hours [3].

Table 2 CCATT spectrum of operation

Humanitarian assistance
• US Million Air cargo airplane crash in Ecuador, October 1996
• Mission to McMurdo Station, Antarctica to evacuate National Science Foundation employee
• 2005 Hurricane Katrina
Military operations other than war
• Haiti invasion (Operation Uphold Democracy).
• Bosnia peacekeeping operation (Operation Joint Endeavor).
• Pullout of U.S. troops from Somalia.
• Khobar Towers bombing (Dhahran, Saudi Arabia).
• Special Operations support during South Sudanese Civil War.
Peacetime movement of critically ill beneficiaries of military health care system
• Within the Continental U.S. and Europe for specialized care such as liver or lung transplant
• Critically ill or injured DoD personnel from the Pacific and Asia back to US
• Support of US President travel to medically remote locations
• Support for landing of astronauts in Soyuz escape module in Kazakhstan
Homeland defense
• Four CCATT Teams deployed to Maguire AFB, New Jersey, in support of the September 11, 2001 tragedy at the World Trade Center/Pentagon.

CCATT operations in the Pacific

Although the primary mission for CCATT since the beginning of operations in Iraq and Afghanistan has been the transport of critical patients within and out of combat zones, there has been an expanding role of CCATT into additional arenas. Examples of the types of missions CCATT has performed since its inception in 1994, outside of the primary combat related mission, are listed in Table 2 below. Since 2010, CCATT has been tasked to transport critically ill and injured patients within the Pacific Region to definitive care in the USA. The Pacific theatre encompasses an area of more than 100 million square miles and covers approximately half the world's surface area. The region includes remote islands with limited health care capabilities and is home to over 170,000 DoD beneficiaries. The CCATT mission experience in this region can differ significantly from that in support of recent military operations in Iraq and Afghanistan. Unlike the combat environment, where experienced surgical and ICU teams perform hand-offs of patients to CCATT, in remote areas in the Pacific, the CCATT physician may be the only individual with expertise in critical care. The patient may have had very limited or no stabilizing measures prior to the arrival of the CCAT team. CCATT is then responsible for stabilizing an unstable patient prior to transport. This differs significantly from the experiences in the OIF and OEF, where patients are prepped for transport in resource-rich environments surrounded by experienced personnel. Examples of remote facilities that have requested CCATT since its inception in the region in 2010 include Kwajalein atoll, Wake Island, Midway Island, Palau, and Diego Garcia in the Indian Ocean.

The closest regional medical facility in the Pacific is Tripler Army Hospital on the island of Oahu, HI. The vast majority of CCATT transports in the Pacific are to Tripler. This facility is nine hours from mainland Japan and can be up to 14 hours from other, more remote facilities like Diego Garcia. There are essentially no divert capabilities in the Pacific. Unlike a combat environment where transport of critical patients is often necessary to allow for treatment of incoming casualties, the decision to transport critically ill or injured patients from countries with advanced health care systems like Japan or Korea needs to be carefully weighed against the risks of transport. An important role of the CCATT physician in this arena is negotiating any linguistic and cultural differences that may be complicating the medical decision making process. Unlike the experiences in the OIF and OEF, where trauma patients have made up the majority of CCATT transport missions [29], in the Pacific, the majority of patients have a critical medical illness. In 2015, there were 30 CCATT missions originating from the Western Pacific. Examples of diagnoses among these patients included, HIV encephalitis with acute renal failure and mental status changes, listeria sepsis with meningitis, myocardial infarct with respiratory failure, fulminant hepatic failure secondary to Tylenol overdose, brain abscess with pneumocephaly, status epilepticus, ARDS, and angioedema with subglottic stenosis (personal communication, Dr. Leslie Wood, Pacific CCATT) .

Specialized transport teams

Acute lung rescue team

Patients with severe lung injury and refractory hypoxia are potentially poor candidates for aeromedical evacuation. In 2005, a specialized Acute Lung Rescue Team (ALeRT) was created [34] to evaluate and transport patients whose ventilatory requirements exceeded or could be expected to exceed the limits of a portable ventilator at altitude, but whose clinical situation otherwise required them to move to a higher level of care which could not be provided at any medical facility within theatre. ALRT has utilized a variety of modalities to successfully transport patients with severe lung injury out of Iraq and Afghanistan including high-frequency percussive ventilation with (VDR), pumpless extracorporeal lung assist device (PECLA), and more recently, extracorporeal membrane oxygenation (ECMO) [35, 36, 37]. The ALRT personnel are stationed at LRMC as their permanent duty station and can be ready to launch within hours of being activated. Members of the team maintain close working relationships with German ECMO center for sustainment of skills [36]. The recent establishment of an adult ECMO center at SAMMC will also advance military capabilities for transport of patients with severe lung injuries.

Burn Flight Team

The Burn Flight Team (BFT) is a specialized transport team established in 1951 that operates out of the US Army Institute for Surgical Research (USAISR) Burn Center, located at the San Antonio Military Medical Center (SAMMC), in San Antonio, Texas [38]. The BFT is a five-person team composed of a burn surgeon, two critical care burn nurses, a respiratory therapist and an operations noncommissioned officer. The US transportation command (USTRANSCOM) has established guidelines for activation of the BFT which include burns involving >20 % total body surface area, inhalational injury, or patients with Pa02 to Fi02 ratio <200, high voltage electrical burn and burns in patients with additional severe traumatic injuries [39]. The BFT is equipped to perform a number of en route emergent procedures including bronchoscopy, escharotomy, fasciotomy, and decompressive laparotomy. During military operations in Iraq and Afghanistan, the BFT transported over 350 patients back to the USAISR facility in San Antonio. Based on the extensive experience with transporting burn patients, often during the first 24 h of injury when the risk of burn shock is very high, Joint Theatre Trauma System Clinical Practice Guidelines have been published on the ISR website (http://www.usaisr.amedd.army.mil).

Future directions of CCATT

Data from OIF/OEF support the notion that US military members in these conflicts are surviving with more significant wounds than in prior conflicts. The fatality-to-wounded ratio is significantly lower than either the Vietnam War or World War II [40, 41]. Improved medical care along the entire spectrum of military combat medicine has been one of a variety of factors that has contributed to the improved overall survival of US service members in these conflicts [42, 43].

In an important 2012 study on combat deaths in Iraq and Afghanistan between 2001 and 2011, Eastridge et al. estimated that up to 25 % of fatal injuries were potentially survivable [44•]. Furthermore, 90 % of deaths occur in the pre-hospital setting. A partnership between a tri-service committee on Tactical Combat Casualty Care (TCCC), the USAISR, and the Joint Trauma System has led to significant advances in pre-hospital care [16]. As a means of further improving pre-hospital care in combat environments, the US Air Force has expanded the CCATT concept to critical care evacuation teams with surgical capabilities. The Tactical Critical Care Evacuation Team (TCCET) has been developed to bring this evolving capability to both rotary and fixed wing aircraft. Patients who are actively hemorrhaging could undergo surgical interventions by the TCCT team either on the ground or, if needed, en route to a surgical support medical facility. Just as CCATT transforms the aircraft into an intensive care unit, TCCET transforms the aircraft into an operating room. The concept could be potentially applicable in more remote areas of Africa or the Pacific where immediate medical care on the ground is not possible due to either tactical or logistical constraints.

Summary

CCATT was designed to meet the demands of evolving US military operations and has proven to be a versatile and effective asset within the larger AE system. During OIF and OEF, CCATT safely transported over 8000 critical patients back to the USA for definitive care often within 48 to 72 hours of

injury. CCATT has also been used for a variety of operations other than war and has recently expanded peacetime operations into the Pacific where remote health care systems and enormous distances create new challenges. As the US becomes increasingly involved in humanitarian missions and smaller, isolated military operations often in more remote areas around the world, there is a need for an increasingly mobile medical support apparatus with advanced critical care capabilities. CCATT and a number of other specialized transport teams continue to evolve their capabilities to meet this demand and maximize survival of US service members anywhere in the world.

Compliance with ethical standards

Conflict of interest Peter Crawley declares that he has no conflict of interest.

Human and animal rights and informed consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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