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Interfacility Transport of Critically Ill Patients

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OBJECTIVES: To assess recent advances in interfacility critical care transport.

DATA SOURCES: PubMed English language publications plus chapters and professional organization publications.

STUDY SELECTION: Manuscripts including practice manuals and standard (1990–2021) focused on interfacility transport of critically ill patients.

DATA EXTRACTION: Review of society guidelines, legislative requirements, objective measures of outcomes, and transport practice standards occurred in work groups assessing definitions and foundations of interfacility transport, transport team composition, and transport specific considerations. Qualitative analysis was performed to characterize current science regarding interfacility transport.

DATA SYNTHESIS: The Task Force conducted an integrative review of 496 manuscripts combined with 120 from the authors' collections including nonpeer reviewed publications. After title and abstract screening, 40 underwent full-text review, of which 21 remained for qualitative synthesis.

CONCLUSIONS: Since 2004, there have been numerous advances in critical care interfacility transport. Clinical deterioration may be mitigated by appropriate patient selection, pretransport optimization, and transport by a well-resourced team and vehicle. There remains a dearth of high-quality controlled studies, but notable advances in monitoring, en route management, transport modality (air vs ground), as well as team composition and training serve as foundations for future inquiry. Guidance from professional organizations remains uncoupled from enforceable regulations, impeding standardization of transport program quality assessment and verification.

KEY WORDS: transport; critical care; critical illness; emergencies; hospitals

Interfacility critical care transport (CCT) refers to the transfer of critically ill patients from one healthcare facility to another, usually for services unavailable at the sending facility. Distinct from acute emergency care and transport to an emergency department, interfacility CCT involves specific planning and communication to ensure safe continuation of a high level of care en route. A prior study found that 4.5% of ICU patients in the United States underwent CCT at some point in their critical illness (1). The importance of CCT has been underscored by patient "load balancing" across facilities during severe acute respiratory syndrome coronavirus 2 surges (2). CCT has also proven essential in the face of escalating care complexity coupled with high-intensity service regionalization (3). The development of healthcare networks and centers with highly specialized services, such as trauma, burn, and extracorporeal membrane oxygenation (ECMO) centers, requires safe CCT to facilitate patient movement (3–5). Critically ill patients can quickly decompensate; thus, providing the best possible team with the appropriate experience to provide safe CCT is paramount (6–9). CCT contrasts with other interfacility transport (non-CCT) moving patients from higher to lower acuity settings such as quaternary care center to a rehabilitation or skilled nursing facility. This review explores current CCT practice and highlights practice advances that

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emerged after the 2004 Society of Critical Care Medicine (SCCM) guidelines (10).

METHODS

Task Force Structure

This SCCM Task Force recruited physician and nurse CCT leaders from emergency medicine, trauma surgery, and surgical/medical/pediatric/cardiothoracic critical care (**Supplemental Statement: Taskforce Member Recruitment and Conflict Assessment**, http://links.lww.com/CCM/H179). Additionally, National A ssociation of EMS Physicians and American College of Emergency Physicians representatives participated as key stakeholders.

Focus Areas

Current CCT practice was assessed in three domains: 1) definitions and practice foundations, 2) team composition, and 3) transport specific considerations. Military CCT and the translation of relevant concepts to civilian CCT were also explored. Although out-of-hospital patient care and initial transport to the hospital by private vehicle, police, or emergency medical services (EMS) were considered for inclusion, they required stakeholders not represented within the Task Force and were not formally assessed. Transport system design and operation was limited to the United States due to substantive differences in international transport practices.

Integrative Review

An integrative review was performed using MEDLINE (1990 to February 24, 2021) limited to English language publications. Retrieved manuscripts (n = 588) were combined with the authors' collections (n = 120). Following duplicate deletion and title/abstract screening using Rayyan (11), 40 remained for full-text review, and 21 (**Supplemental Table**, http://links.lww.com/CCM/H180) were considered in the qualitative synthesis using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses approach (**Fig. 1**).

RESULTS

CCT advances in operational and clinical practice after the 2004 SCCM CCT guideline (10) are shown in **Table 1**.

Definitions and Foundations

CCT Definition. CCT is the practice of moving critically ill patients by ground, air, or water-surface vehicle from one medical facility to another. Specialized teams ensure that en route care meets patient needs to ensure safety. Accordingly, care intensity and quality will meet that of the originating facility and may vastly exceed it if the transport team provides unique care such as ECMO rescue.

In 2006, the Institute of Medicine (now the National Academy of Medicine, NAM) recommended regionalizing services for stroke, ST-segment elevation myocardial infarction, major trauma, and pediatric critical care to improve quality and reduce variations in care delivery (30–32). Regionalization has driven both CCT utilization and practice evolution (33, 34). With these changes, CCT consistently enables safe patient flow from more remote critical access facilities into centralized facilities with more complex capabilities in a "hub and spoke" model.

CCT is pursued using two models—retrieval or transfer. The retrieval system dispatches an accepting facility CCT team to optimize the patient at the referring facility and then complete transport to the accepting facility. The transfer model leverages referring facility teams in concert with local EMS to transport the patient to the accepting facility. The transfer model offers the advantage of efficiency—provided an accepting facility bed is available—but may deplete local personnel (33, 35–37). Retrieval teams are also necessarily aligned with bed availability at the accepting facility but may not be immediately available if the team is already engaged in transferring a patient from another facility when the next request for patient transfer is generated. Accordingly, a transfer team may serve as contingency plan when a retrieval team is unavailable, but an appropriate receiving facility bed exists. Regardless of which approach is selected bed availability is a key issue. Patient throughput, bed staffing, and surgical case volume all impact bed availability and CCT timing; such logistical issues may be best addressed on a local level at the receiving facility.

From the perspective of the originating facility, a transfer team may afford the most expeditious approach, as the patient need not await the dispatch and arrival of a retrieval team. Furthermore, transferring facilities tend to be smaller that receiving facilities and may have fewer ED beds for acute care. Being

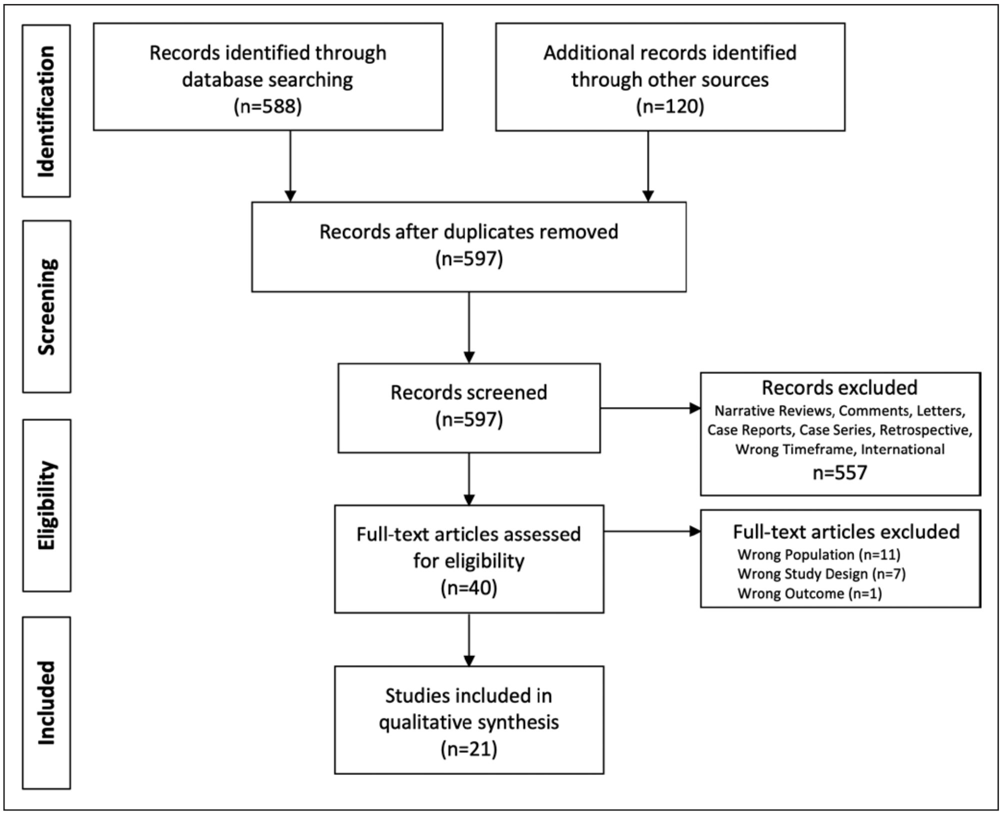

Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow diagram for integrative review article selection. The literature review included manuscripts ($n = 110$), guidelines ($n = 7$), and nonpeer-reviewed chapters ($n = 3$) identified in the authors' collections of manuscripts on the topic of interfacility transport cross-referenced with a MEDLINE search conducted with the assistance of a medical librarian (Maylene Qiu, University of Pennsylvania Biomedical Library) using the following search terms limited to articles written in English from January 1990 to February 2021: ((((“transportation”[MeSH Terms] OR “transportation”[tiab] OR “transportations”[tiab] OR “transported”[tiab] OR “transporter s”[tiab] OR “transporting”[tiab] OR “transports”[tiab] OR “transporter”[tiab] OR “transporters”[tiab] OR “transportable”[tiab] OR transport [tiab]) OR (transportation of patients [MeSH])) OR (air ambulance [MeSH])) AND (((((((“critical care”[MeSH Terms] OR critical care [tiab] OR (critical [tiab] AND care [tiab])) OR (“critical illness”[MeSH Terms] OR (critical [tiab] AND illness [tiab]) OR (critically [tiab] AND ill [tiab]))) OR (intensive [tiab] AND care [tiab])) OR (“ICUs”[MeSH Terms] OR “ICUs”[tiab])) OR (“emergencies”[MeSH Terms] OR “emergencies”[All Fields] OR “emergency”[tiab] OR “emergent”[tiab] OR “emergently”[tiab] OR “emergents”[tiab] OR “emerges”[tiab] OR “emerging”[tiab] OR “emerge”[tiab] OR “emerged”[tiab] OR “emergence”[tiab] OR “emergences”[tiab])) OR ((critical [tiab] OR critically [tiab]) AND (condition [tiab] OR conditions [tiab] OR disease [tiab] OR diseases [tiab] OR injury [tiab] OR injuries [tiab] OR wounds [tiab] OR wounded [tiab]))) OR (trauma [tiab] OR traumatic [tiab]))) AND (((“hospitals”[MeSH Terms] OR “hospitals”[tiab] OR “hospital”[tiab]) AND (interfacility [tiab] OR “interhospital”[tiab] OR “inter-hospital”[tiab]))). One author (J.W.C.) screened by title and abstract to identify guidelines, systematic reviews, interventional trials, and prospective observational studies. Two authors (S.R.W., J.W.C.) then performed full-text review of the identified articles for final inclusion. Of the records from the authors' collections, $n = 8$ ($n = 7$ manuscripts and $n = 1$ guideline) met all inclusion criteria and were considered in the final qualitative synthesis. This integrative review was not registered, and a formal Grading of Recommendations, Assessment, Development and Evaluations analysis of included studies was not conducted.

able to rapidly move patients awaiting transfer to their intended destination may help alleviate ED “boarding” of such patients (38). Similarly, using a transfer team may more also help clear originating facility ICU beds of patients awaiting transfer episodes of unanticipated patient surge. Nonetheless, challenges in discharging floor patients to an appropriate location, so that ICU patients may be transferred to the floor remain issues that can impact CCT timing and may be best addressed on a local level.

Regulatory Considerations. The 1966 Highway Safety Act established the Department of Transportation's National Highway Transportation Safety Administration (NHTSA) as the de facto governance agency for EMS including CCT. However, although regulations regarding EMS were promulgated, no regulations specifically covered interfacility transport. A 2003 NHTSA working group articulated general transport industry guidelines but lacked regulatory empowerment (39). Accordingly, U.S. Federal CCT regulations widely vary by municipality, county, region, or state thereby fostering disparate practices and standards. These differences make transport across state lines problematic with regards to licensure, credentialing, and billing during disaster, crisis, or pandemic response (40). Although temporary licensure across state lines was used by some neighboring states to fill clinician gaps during COVID-19 surges, such adaptation required a significant crisis to drive these adjustments.

TABLE 1.
Changes in Critical Care Transport Since 2004

Category	Interventions	Examples
Operational	Substantial growth in rural based helicopters	Rapid changes in helicopter density from 545 in 2003 to over 1200 in 2021 (12)
	Development of national and international transport agencies	AirMed International; DOD Adult ECMO Transport Team
	Increasing regionalization of healthcare	Development of high-volume centers of excellence (e.g., trauma centers, stroke centers) (3, 13)
	Emphasis on interprofessional approach	Maximizing scope of practice for nonphysician teams, using off-line medical direction. Examples include rapid sequence intubation (14), finger thoracostomy (15)
	Telemedicine	Use of videoconferencing to allow the team to directly communicate with the receiving hospital (16)
Clinical	Adaptation of military procedures	Many critical care transport services now carry packed RBCs and plasma (17, 18) Use of tranexamic acid for early hemorrhagic shock, minor traumatic brain injury (19, 20) Use of hemostatic gauze (21)
	Advances in airway management	Use of videolaryngoscopy (22) Increased use of noninvasive ventilation (23)
	Application of modern critical care management to transport	Use of lung-protective ventilation in transport (24) Transport on ECMO and other mechanical circulatory support devices (25–27) Enhanced strategies to manage transport of patients with highly contagious pathogens (28, 29)

ECMO = extracorporeal membrane oxygenation.

Regularly recurring CCT to a quaternary care facility across state line (based on proximity) would benefit from an established process for creating a transport license that could be implemented at either the state or federal level. Such a complex process is outside the purview of medical professional organizations but could be raised through advocacy efforts.

Emergency Medical Treatment and Labor Act. Perhaps the most important federal regulation impacting transport is the 1986 *Emergency Medical Treatment and Labor Act* (EMTALA). Under EMTALA, a patient is considered "stable for transfer" if the treating physician determines that material deterioration is unlikely to occur during transfer. When there is instability (hemodynamic, neurologic, or other), the hospital may transfer the patient if a physician certifies that transfer benefits outweigh risks, or if the patient provides a written request after being informed of transfer risks and the referring hospital's obligation to provide care (41, 42). EMTALA ties the responsibility for patient care, interfacility transport team composition, equipment, and selection to the sending physician.

EMTALA's national scope may conflict with local and state regulations, particularly regarding care responsibility during CCT. Under EMTALA, treatment orders en route must flow from the sending physician. When patients undergo CCT by transfer teams, the rendered care is determined by the sending physician and facility. Retrieval teams, on the other hand, act under the direction of the receiving facility and accepting physician; in this way, the accepting physician functionally "sends" the transporting team to the patient. Thus, the en route responsibility for patient care orders will vary based on the origin of the transporting team but remain tied to the "sending" physician. Nonetheless, many states require a physician to be credentialed as a Medical Director to provide orders to out-of-hospital transport teams. This creates uncertainty regarding liability for untoward events as different states require different practices regarding CCT.

State Regulations. Regulations and statutes that govern EMS practice may vary greatly across state or municipal boundaries (43). For example, 33 different EMS entities established local protocols and EMS professional certification processes in California. In some jurisdictions, the transport team is held to the standards of their base of operations, whereas other jurisdictions bind standards to that of the receiving facility's location.

The National EMS Scope of Practice, funded by NHTSA, endorses a standardized nomenclature and skillset for EMS clinicians (43). Although focused on prehospital care, this document provides consistent language that may be used to guide CCT teams that may cross borders where standards change based on locale and not clinical imperatives.

Pretransport Coordination. High quality CCT requires careful patient selection coupled with appropriate receiving facility selection and relies on well-trained team members to deliver care that mitigates against transfer-associated adverse events (44–48). Although EMTALA places transport care responsibility with the transferring physician, documented consultation with the receiving physician may help mitigate risk. Templates for such discourse may be generated as part of transfer agreements or exist as stand-alone documents when the facilities use noninteroperable electronic health records. Indeed, transfer agreements often reflect resource limitation at the originating facility that drive CCT initiation to secure specific resources or complex care required for patient management. If the receiving facility uses a transfer center that coordinates a facility employed transport team, responsibility may be shared between the transferring physician and the receiving facility. Additionally, establishing a protocol to record all transfer-related phone calls is invaluable in engaging in quality improvement (QI) and assessing program performance.

Telehealth platform deployment facilitates comanagement and optimization prior to or even during transport (49, 50). Perhaps most importantly, the decision to transfer—or not transfer—may be jointly reached using telehealth. Patients appropriate for transfer demonstrate needs that exceed available local resources, including bed availability, offered interventions, or specialists (46). The sending clinician ideally documents that transport—despite risks, costs, and distance from family support—is likely to enhance survival (51, 52). Retrospective reviews find that transferred patients experience outcomes better than those predicted by Acute Physiology and Chronic Health Evaluation (APACHE) II or III scores (53, 54).

Part of supporting excellent outcomes in clinician-to-clinician handoff from the originating to the receiving facility, so that previously delivered care—and the patient's response—is clearly understood ahead of transfer. This process is also supported by a similar handoff from the transport team to the receiving inpatient team. Although there is no universally accepted handoff tool or checklist, a process that gathers relevant clinicians at the bedside, directly shares information, and affords an opportunity ask clarifying questions or to extract additional information is ideal and may mitigate the need for emergent interventions or management changes upon arrival (55). This approach mirrors the well-characterized postoperative to handoffs and transitions in critical care (HATRICC) that brings the anesthesia, surgery, and ICU teams together at the bedside for a single structured exchange of information (56, 57).

Adverse events occur in 5–28% of CCTs (58–66). Invasive mechanical ventilation, hypoxemia despite 50% oxygen, and vasopressor unresponsive hypotension reflect the high-risk CCT patient population (60, 61, 67, 68). Desaturation (28%) and hypotension (17%) occur with sufficient frequency to guide team preparation and quality surveillance (59, 66, 69). Equipment malfunction is reported in 15.6% of CCT driving the need for essential equipment failure preparation (68). Adverse event mitigation and high-quality patient care rest on dedicated CCT teams with members who develop transactive memory around both the planning and execution of complex transport, including patient preparation for safe CCT (61, 69–71). Events en route should be communicated to the receiving facility to facilitate changes in admission planning or required therapeutic urgency (e.g., rapid operating room, angiointervention, ECMO).

CCT Team Composition

Team Membership. CCT services are ideally delivered by specialized and dedicated transport team members rather than provisional participants. Multiprofessional CCT teams may include nurses, paramedics, physicians, advanced practice providers, perfusionists, or respiratory therapists. Team configuration optimally reflects specific skill requirements, rather than a uniformly embraced mix; this domain remains devoid of robust data within the United States (10, 35, 72–74).

Ideal retrieval CCT team composition incorporates at least two clinicians trained to provide care consistent with critical care in a tertiary facility (10, 33, 35, 37); additional members should reflect specific patient needs. Most U.S. air medical CCT programs operate with a nurse/paramedic crew, whereas ground programs primarily operate using a paramedic/paramedic configuration (44, 75–77). For pediatric transports, nurse/nurse or nurse/respiratory therapist models appear most common (73). These differences reflect unique care needs, as well as the lack of uniformity in establishing a base crew to which other team members may be added.

Medical transport professional associations such as the Air and Surface Transport Nurses Association and the International Association of Flight and Critical Care Paramedics have defined the scope of practice for flight—but not ground transport—crews (78, 79). Studies evaluating paramedic transport document preserved physiology (as assessed by APACHE II scores), and fewer adverse events with critical care certified paramedics compared with those without such certification suggesting that the expanded scope of practice afforded by paramedic certification supports favorable care outcomes (61, 80). The impact of advanced training—but not necessarily team composition—in supporting safety is both intuitively obvious and supports ongoing education in a focused fashion.

Despite the intuitive attractiveness of physician CCT team members, their inclusion remains controversial and devoid of supporting data within the United States (81). Furthermore, individual associations address neither transport physicians or other clinicians (physician assistants, nurse practitioners, respiratory therapists [RTs]), nor their scope of practice during transport. Studies comparing a physician/nurse versus nurse/nurse pediatric transport team or nurse/paramedic versus nurse/nurse teams indicate similar outcomes and adverse events (70, 82). Neither hemodynamic stability on arrival nor procedure success is adversely impacted by U.S. CCT teams deployed without physician members (82, 83). Physician trainees in emergency medicine, pediatrics, or critical care require some exposure to prehospital care and interfacility transport within the confines of an accredited training program. Therefore, U.S. CCT teams intermittently include transient physician members. Other CCT models such as those of the European Union and the United Kingdom routinely include physician members (79, 84, 85).

Dedicated CCT Teams. Improved outcomes and transport logistics accrue when CCT teams demonstrate expertise in acute respiratory distress syndrome, burn, major trauma, and extracorporeal support management (86–88). Studies principally consist of case series and single institution retrospective reviews indicating a need for high-quality inquiry (89, 90). Nonetheless, current data suggest that pretransport optimization, en route adverse events, and mortality are favorably impacted by specialized adult or pediatric CCT teams (71, 72, 91–95).

When a specialized team is unavailable, itinerant teams may be assembled using personnel from either the originating or receiving facility. This approach is most commonly used for interfacility neonatal, pediatric, or cardiac assist device requiring CCT (72, 96). In-hospital knowledge and skills may not translate to transport realities; therefore, CCT participating members are ideally specifically trained in out-of-hospital care (73, 97). One ideal example of a dedicated team focused on team dynamics and out-of-hospital complex care is found within the U.S. military.

Military CCT. Military CCT teams differ from their civilian counterparts since they must respond to combat realities (98–100). Tactical considerations including prolonged field care, multicasualty event management, multiple team transitions, team member interoperability, and variable transport lengths are uncommon in civilian CCT. Nonetheless, military experience informs civilian practice including CCT during mass casualty events, disasters, and ICU evacuation (101, 102). Rapid and staged evacuation through multiple levels of care characterizes military CCT. Therefore, in the mid-1990s, the U.S. Air Force developed the Critical Care Air Transport Team (CCATT) program training and deploying teams comprised of a critical care physician, critical care nurse, and respiratory therapist. Notably, CCATTs completed 3,000 long-range transports during Operations Iraqi Freedom and Enduring Freedom with excellent survival and maintained care quality despite long transport durations (103).

Civilian CCT Training. Air medical transport requires the clinician to manage evolving patient needs in a challenging environment. CCT also expands the range of clinical conditions that a team member will need to manage beyond their primary field and does so in a location generally without the panoply of resources on which inpatient clinicians rely. To meet this reality, CCT-focused organizations have developed education standards and clinician orientation and competency assessments.

Unsurprisingly, training regimens as well as onboarding programs demonstrate substantial variability, especially since personnel and transport equipment requirements are not legally nor regulatorily defined. Accordingly, organizations and CCT agencies and their Medical Directors may deploy divergent approaches to field deployment of appropriately "trained" individuals (73). Unlike board certification requirements in many medical fields, CCT remains less well-regulated. Nonetheless, certain commonalities are shared across agencies.

Most agencies require CCT clinicians to maintain basic life support, advanced cardiac life support, and pediatric advanced life support, or equivalent certifications. Additionally, many require Neonatal Resuscitation Program or Sugar, Temperature, Airway, Blood pressure, Laboratory work, and Emotional support certification for high-risk obstetrical or neonatal patient transport; Advanced Trauma Life Support, and Advanced Trauma Care for Nurses, or Trauma Nurse Core Course is generally required for injured patient transport. Other CCT services also require SCCM's Fundamentals of Critical Care Support (FCCS) courses (FCCS, Pediatric FCCS, FCCS: Obstetrics). However, CCT agencies do not embrace a common approach to baseline training requirements, representing an opportunity for variation reduction going forward.

Professional Specialty Certification. Despite CCT agency requirement variability, some professional organizations offer clinician certifications (**Table 2**). Professional specialty certifications document minimum competency using standardized assessments of a core body of CCT practice-specific knowledge. Medical transport systems may be voluntarily assessed by an international organization that applies consensus standards, updates every 3 years, incorporates

TABLE 2.
Professional Speciality Certifications in Critical Care Transport

Specialty	Professional Association	Professional Certification	Licensure
Paramedic	International Association of Flight and Critical Care Paramedics	Certified Flight Paramedic Certified Critical Care Transport Paramedic Administered by the International Board of Specialty Certification (https://www.ibscertifications.org/)	By state, region, or county
Registered nurse	Air and Surface Transport Nurses Association	Certified Flight Registered Nurse Certified Transport Registered Nurse Administered by the Board of Certification for Emergency Nursing (https://bcen.org/)	By state
Physician	Air Medical Physicians Association	Offers the Medical Director Core Curriculum process Physician certification options are available in other countries Australia (https://acem.org.au/Content-Sources/Certificate-and-Diploma-Programs/Pre-Hospital-and-Retrieval-Medicine) Canada, Diploma in Prehospital and Transport Medicine (Area of Focused Competence) (https://www.royalcollege.ca/rcsite/documents/ibd/prehospital-transport-medicine-afc-sa-e.pdf)	By state
Respiratory therapist	National Board of Respiratory Care	Registered Respiratory Therapist (entry level practice) There are no flight or ground transport specific certifications. Certified Pulmonary Function Technologist Registered Pulmonary Function Technologist Adult Critical Care Specialist Neonatal/Pediatric Specialist Sleep Disorders Specialist	By state

public comment, and on-site peer review to credential programs. The Commission on Accreditation of Medical Transport Systems (CAMTS) fills this function. CAMTS is comprised of 21 nonprofit transport-focused medical professional organizations and is a member of the American National Standards Institute. CAMTS has required clinician specialty certification within 2 years of hire for more than a decade (97). The specialty certification requirement dovetails with subspecialty critical care certification in paramedicine (104). Nonetheless, routine CCT utilization of such certified personnel remains limited, even in evolving consolidated care networks or critical care organizations (105).

CCT Unique Considerations

Transport Method. CCT methods include ground vehicle, rotor- (helicopter) and fixed-wing aircraft, and occasionally water surface vessel. Ideally, the transport method selected will minimize the out-of-hospital time and ultimately the time to definitive critical intervention. Ground transport is simplest for short distances due to vehicle availability and obviates secondary transfers from helipads or airports required for aeromedical CCT. Unfortunately, ground transport is subject to delays related to traffic, speed limits, terrain barriers, and untoward weather (106).

Helicopter transport can be useful for short-to-intermediate distances and time-sensitive conditions. Helicopters are more weather sensitive than ground vehicles, and most civilian helicopters remain grounded during icing conditions. Mission approval, weather, and prelaunch aviation checks define a complicated process that may delay air transport (107, 108). Lack of an on-site helipad at the sending or receiving facility can offset potential time savings compared with ground transport (108).

Fixed-wing transport is ideal for long distances due to greater speed and weather resilience compared with helicopter transport. Although fixed-wing aircraft fly at higher altitudes than helicopters, cabin pressure may be adjusted to reduce the adverse event risk when patients have gas volume driven altitude sensitive conditions (e.g., bowel obstruction, unresolved pneumothorax). Furthermore, fixed-wing transport requires an airport at which to land and then transfer the patient to a vehicle for secondary ground transport. The inherent time cost of patient transfer between vehicles may eliminate the value of fixed-wing transport over shorter distances.

Although water surface ambulance services are primarily designed for emergency scene response, they may also provide interfacility transfer in certain locations. Nonetheless, like fixed-wing transport, water surface ambulance transport generally also necessitates secondary ground transport to reach the receiving facility. Marine interfacility transport may be a primary or backup strategy when air transport is unavailable and ground transport is not possible (e.g., between island-based and mainland hospitals).

Distance and time provide a useful guide to selecting ground versus air transport (109, 110). In general, transport less than 50 miles (80 km) can be met by ground ambulance, 50–150 miles (80–240 km) by helicopter, and greater than 150 miles (> 240 km) by fixed-wing aircraft. Each of these distances is also accompanied by an assessment of total transport time, particularly for time-sensitive conditions such as myocardial ischemia, intracranial hemorrhage, stroke, or severe injury in which time may be saved by using aeromedical CCT even over short geographical distances. Transport mode selection benefits from an operational assessment incorporating weather, landing or delivery site availability, distance between locations requiring secondary transport, and resource availability. Therefore, transport preplanning from common referral or origination sites supports transport timeliness as well as safety planning.

Clinically relevant outcomes parsed by transport mode remain limited and conflicting (111). Most studies are observational or combine scene rescue with interfacility transport data. Severe injury and conditions requiring angiointervention may benefit from air transport, but the data are less compelling for other conditions (112–117). Accordingly, fixed-wing transport may be optimal when long distance travel is required, perhaps best exemplified by military CCATT outcomes (118). Selective, compared with routine, helicopter CCT avoids the expense and over-triage associated with unnecessary deployment (119–123).

Equipment and Supplies. Current data suggest that CCT vehicle equipment and supplies be standardized and reflect the specifics of the transport mission (**Table 3**). Given transport vehicle weight and space constraints, equipment and supplies benefit from

TABLE 3.
Essential Equipment for Critical Care Transport

Category	Examples
Monitoring of vital signs	Continuous rate and rhythm monitoring, O_2 saturation, noninvasive blood pressure, and respiratory rate. Continuous or intermittent 12-lead electrocardiogram monitoring in cardiac or toxicology patients. Continuous or intermittent temperature measurement in targeted temperature management patients. Invasive hemodynamic monitoring (arterial line, pulmonary artery catheter). Quantitative end-tidal carbon dioxide monitoring for all intubated patients. Fetal heart rate checks for pregnant patients (128, 129).
O_2 and respiratory support	Supply of O_2 in the vehicle and in moving the patient between the vehicle and facilities. Basic airway management equipment, such as a bag-mask ventilation device and oral/nasal airways, supraglottic airways, and functioning suction. Difficult airway equipment, including video laryngoscopes and instruments for surgical airways. Critical care transport transport ventilators with controlled and spontaneous breathing mode options, appropriate volume and pressure alarms, and ability to deliver positive end-expiratory pressure to at least 20 cm H_2O.
Medications and delivery devices	Infusion pumps—types will vary depending on the scope of practice of the team. Medications, including sedation agents, analgesics, vasopressors, inotropes, neuromuscular blockers, antimicrobial agents, antiarrhythmics, bronchodilators, heparin infusions, and insulin (130).
Diagnostic equipment	Point-of-care laboratory testing (131–134). Point-of-care ultrasound for diagnostic purposes and image-guided procedures during transport (135, 136).

miniaturization and must be securable to ensure crew and patient safety (124). Appropriate storage for sensitive supplies (e.g., medications needing refrigeration, blood products) influences existing vehicle revision and guides new vehicle design. Air transport equipment optimally passes testing at operational altitude that also confirms that the device will not interfere with aviation-sensitive electronics (125). En route drone delivery of unanticipated medications or blood components may soon mitigate against the risk of depleting supplies during CCT (126, 127).

Portable monitors are essential to track frequent vital signs and guide therapy in all CCT patients along with end-tidal carbon dioxide monitoring for those who require invasive mechanical ventilation (137–139). Monitors may draw power from the transport vehicle but must also have batteries for patient movement. Some monitors incorporate a night vision goggle compatible display option. This feature is generally unnecessary for ground or water-based transport but may be helpful for air transport. Since traditional audible feedback may be compromised by vehicle or environmental noise, visual cues are essential for transport monitors.

Since CCT is a planned event, both civilian and military CCT must ensure sufficient oxygen for patient care as well as a buffer supply in case of transport delay or increased oxygen requirement (140). Compared with all others, the high-flow nasal cannula device oxygen consumption generates the greatest risk of oxygen depletion (141, 142). CCT transport ventilators ideally mirror conventional ICU ventilator capabilities and the CCT team must be trained to manage and troubleshoot the device, especially in teams deploying without an RT (24, 143, 144). Since invasive mechanical ventilation often benefits from continuous infusion of a sedative and an analgesic, infusion should rely on pump delivery rather than a manual device or drop count due to inaccuracies inherent to the latter two approaches (145) Furthermore, infusion pumps include medication libraries that ensure adherence to safe infusion variables, provide safety alarms, and operate using battery power.

Pretransport Optimization. A series of standard assessments that promote pretransport optimization and support transport safety are presented in **Figure 2** (55, 146–149). The period between recognizing the need for CCT and transport team arrival provides an opportunity for the originating facility team to continue to normalize the patient's physiology. Some patients may benefit from further optimization by the CCT team. Such intervention may include placing an oral endotracheal tube, inserting central venous access, initiating a vasopressor infusion, or placing the patient on ECMO.

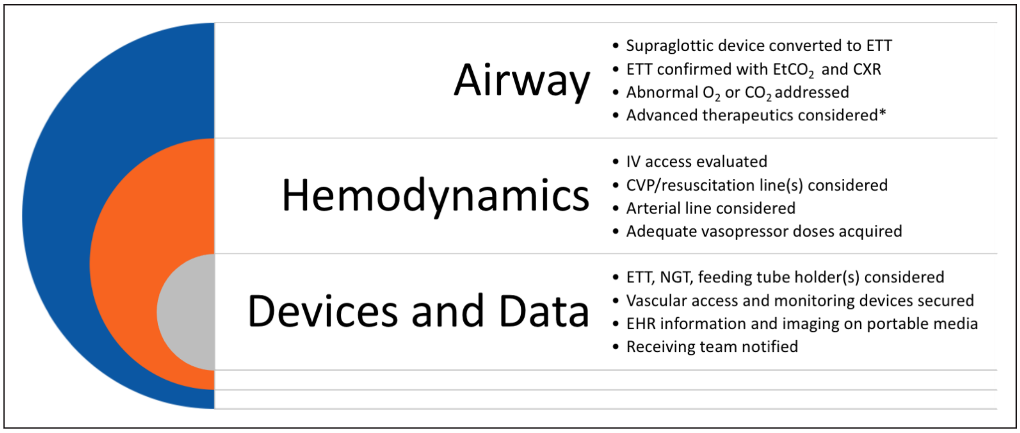

Figure 2. This graphic conveys key pretransport interventions to support optimization as well as transport safety including those related to airway security, hemodynamic performance, device security to prevent premature removal during transport, and essential data transmission. *Advanced therapeutics include pulmonary artery vasodilators, vasopressors, invasive devices such as an intra-aortic balloon pump, or ventricular assist device, or extracorporeal membrane oxygenation. CVP = central venous pressure, CXR = chest radiograph, EHR = electronic health record, $Etco_2$ = end-tidal carbon dioxide, ETT = endotracheal tube, NGT = nasogastric tube.

Other patients may not achieve optimization using only medical measures, and transport should not be delayed for attempted medical optimization (150, 151). Select patients with surgical emergencies may benefit from an initial surgical procedure to afford source control (e.g. debridement of necrotizing soft-tissue infection) or to reverse abnormal physiology (e.g., decompressive laparotomy for abdominal compartment syndrome) while awaiting CCT arrival. A secure, durable method of interfacing with originating and receiving facilities and a Medical Director during transport is essential, as the CCT team may encounter circumstances that require diverting to a site different from the planned receiving facility or landing location.

Medical Oversight. Physicians engage with CCT teams within three domains: 1) serving as medical director, 2) participating in CCT program quality initiatives and other activities, and 3) providing "medical command" during real-time transport (152, 153). The NAM endorses physician leadership as a means to enhance and maintain transport agency effectiveness, especially for CCT (154). An agency medical director bears the responsibility for clinician education, competence, credentialing, protocol and policy development, QI, as well as recruitment, performance evaluation, and related job actions. The medical director may be involved in mission authorization and utilization inquiries as well as reimbursement appeals (153).

Some states describe explicit requirements for the medical director role. Professional associations have elaborated standards and resources for medical director qualification and practice (97, 152, 153, 155). The CCT program and medical director relationship benefit from being executed by contract within which clear performance expectations and provided support are detailed. Depending on requirements, the medical director role may be full-time or can be enfolded within another clinically aligned role tied to an acute care facility. Multiple individuals are generally required to fill this role for a busy agency, with one medical director serving in a lead position.

Quality Improvement. CCT safety and outcome optimization are driven by the NAM's approach: measuring, reporting, and improving care delivery (156). Current QI efforts are supported by digital health records, interrogatable devices, and large data set analysis including the publicly accessible National Emergency Medical Services Information System database (157, 158). Posttransport analysis that explores successes, untoward events, near misses, safety issues, and potential solutions serves as an "after action" assessment to drive QI efforts; such a process is embedded in military teams, and current evidence supports a similar process informing civilian practice (159, 160). Relevant metrics may flow from standard quality care domains that assess care as safe, timely, effective, equitable, efficient, and patient-centered. Evaluated metrics may reflect team composition and skills as well as existing opportunities for improvement; metrics that are specific to unique teams may be similarly elaborated and assessed. Certifying agencies such as CAMTS or state EMS regulatory agencies and quality groups such as the Ground and Air Medical Quality in Transport collaborative help evolve meaningful metrics. Unlike acute inpatient care facility metrics, many of which are publicly reported, CCT agencies do not operate under such a mandate.

Research in CCT. Regardless of the guidance or local standards under which CCT agencies operate, CCT activity is captured within the publicly available National Highway Transportation and Safety Agency's National EMS Information System (NEMSIS). The data within NEMSIS include EMS activations as well as CCT undertakings. This database not only houses national elements but also allows states and local agencies to select elements from the larger database that are relevant to their practice; NEMSIS also provides a public data report (158). NEMSIS helps assess practice and outcomes and is primarily designed to capture data from 911 EMS calls. However, interfacility transport is also captured and therefore serves as the largest compilation of EMS activity in the nation. Therefore, it supports assessments of CCT and non-CCT using standardized national data covering topics from pediatric airway management to the risk of COVID-19 patient deterioration during transport (161, 162). This database is agnostic to local guidelines or protocols and provides data that may inform approaches to standardize CCT training, credentialing, licensure, and team composition in the United States.

LIMITATIONS

This integrative review focused on U.S.-based current practice and thus may be limited in its generalizability to non-U.S. countries. Furthermore, the general low quality of current evidence precluded formal systematic review and meta-analysis thereby limiting our ability to make definitive management recommendations or employing an analysis structure such as Grading of Recommendations, Assessment, Development and Evaluations. We did not assess CCT of nonhuman subjects—including service animals, animal officers, or dogs attached to tactical teams (civilian or military)—but note that such transport occurs and may benefit from a similar structured assessment. We did not include patients or family members in this review and cannot incorporate their perspectives. Nonetheless, the intent was to detail changes in U.S. CCT since 2004 and not to make specific recommendations for changes in practice. Similarly, we did not explore receiving facility preparation for transferred patient care as we solely focused on events that impact transport but not aftercare. Receiving facility preparation to support patient transfer within Critical Care Organizations has been well explored in other publications (105, 163).

CONCLUSIONS

This integrative review identified numerous CCT advances since 2004 supporting the movement of critically ill patients into complex health systems, as well as between facilities within a single health system. CCT leverages a variety of transport modes and vehicles spanning ground, rotary- and fixed-wing, and water-surface craft. However, team composition, certification, credentialing, and licensure requirements all remain nonuniform. Technologic advancements have enabled modern CCT teams to bring quaternary center care to outlying facilities for patient rescue, including mobile ECMO. Unlike other countries, physician engagement in U.S. teams focuses on team leadership and medical direction rather than field deployment. Both medical professional organizations and transport-focused organizations have the opportunity to help guide the future of CCT, including standardizing best practice.

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