Chapter 191 Air Medical Transport

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PERSPECTIVE

The history of air medical transport (AMT) dates back to World War I. The French Air Services evacuated soldiers from Serbia using fixed-wing aircraft (airplanes) as ambulances as early as 1915. The first recorded use of a U.S. military air ambulance was in 1918 when an airplane was converted to accommodate a patient in a semirecumbent litter in the rear cockpit. In 1926, the United States Army Air Corps was formed and flew injured troops more than 150 miles from Nicaragua to a hospital in Panama. In World War II, more than 1.1 million sick and wounded soldiers were airlifted to the United States during the last 3 years of the war. The Korean War introduced the rotor-wing aircraft (helicopter) to AMT. In August 1950, a Bell 47 flew the first of more than 20,000 medical evacuations in Korea. Wounded servicemen were strapped to litters outside the aircraft and transported from battalion aid stations to waiting hospital units. During the Vietnam War, Operation Dustoff transported nearly 1 million injured patients to hospitals.

The impact of AMT on the wounded soldier can be shown by comparing time to definitive care and mortality. During World War II, the average time from injury to definitive care was 6 to 12 hours, with a mortality rate of 5.8%. In Korea, the time was 2 to 4 hours, with 2.4% mortality. In Vietnam, the time was 65 minutes, and mortality was less than 1%.[1] Encouraged by the military experience, civilian AMT in the United States was propelled by the 1969 start of the first hospital-sponsored, fixed-wing air medical program. The first civilian helicopter emergency medical services (HEMS) program in the United States was established in 1972.

AVIATION PHYSIOLOGY

A working knowledge of aviation physiology is vital to understanding the effects of AMT on pilots, medical personnel, and patients.

Boyle's Law

The cornerstone of aviation physiology is *Boyle's law*, which states that the volume of a unit of gas (a specified number of molecules) is inversely proportional to the pressure on it. In concrete terms, Boyle's law means that as altitude increases (and atmospheric pressure decreases), the molecules of gas grow apart, and the volume of the gas expands. With descent (increasing atmospheric pressure), the molecules are condensed, and gas volume contracts.

Physiologic difficulties from expansion and contraction of gases within the closed spaces of the body may occur with any change in altitude. Squeeze injuries occur on descent and are common causes of barotitis and barosinusitis. Air trapped within the sinus or middle ear cavities cannot be equalized with ambient pressure, and the air within the space contracts, pulling mucosal and neurovascular elements with it. Reverse squeeze injuries occur on ascent. The decrease in barometric pressure leads to an increased volume of the air trapped within the space, exerting pressure on adjacent bony, neurovascular, or parenchymal structures. Ascent injuries can also include barotitis media, barosinusitis, conversion of a simple pneumothorax into a tension pneumothorax, and rupture of a hollow viscus by expansion of intestinal gas. The operation of medical equipment containing closed air space can also be affected. Intravenous flow rates, the pressure in air splints and in pneumatic antishock garment suits, and endotracheal tube cuff volumes may be altered with altitude.

Charles' Law

Charles' law follows from the volume effects of Boyle's law. *Charles' law* notes that as the temperature on a volume of gas rises, the volume of the gas also increases. The molecular dispersion seen with increases in gas volume at altitude (Boyle's law) means there is less chance of molecular collision with resulting generation of heat. Charles' law explains why the ambient temperature decreases with increased altitude.

Dalton's Law

Dalton's law states that the total barometric pressure at any given altitude equals the sum of the partial pressures of gases in the mixture ($P_t = P_1 + P_2 + P_3 \ldots P_n$). As pressure is reduced, expansion of gases creates increasing distances between molecules, and the quantity of oxygen available for respiration decreases. Although oxygen still constitutes 21% of the atmospheric pressure, each breath brings fewer oxygen molecules to the lungs, and hypoxia results (Table 191-1). The clinical effect of Dalton's law is manifested as a decrease in partial arterial oxygen tension with increasing altitude.

The most threatening feature of hypoxia is its insidious onset. Physiologic responses include an increased rate and depth of respirations and an increase in heart rate. With prolonged exposure, oxygen supply to the brain is insufficient to support cerebral metabolism. Signs and symptoms of cerebral

Table 191-1 Effects of Altitude on Oxygenation

ALTITUDE (FT)	BAROMETRIC PRESSURE (MM HG)	Po_2 (MM HG)	PAo_2 (MM HG)	$PAco_2$ (MM HG)	OXYGEN SATURATION (%)
Sea level	760	159.2	103.0	40	98
8,000	565	118.4	68.9	36	93
10,000	523	109.6	61.2	35	87
15,000	429	89.9	45.0	32	84
18,000	380	79.6	37.8	30.4	72
20,000	349	73.1	34.3	29.4	66
22,000	321	67.2	32.8	28.4	60

Pao_2, partial pressure of alveolar oxygen; $Paco_2$, partial pressure of arterial carbon dioxide.

hypoxia include headache, nausea, drowsiness, fatigue, and, finally, unconsciousness and death. Although the onset and severity of symptoms may vary with individuals, no one is exempt from the effects of hypoxia, including patients and air medical flight crew.

Henry's Law

Henry's law states that the mass of gas absorbed by a liquid is directly proportional to the partial pressure of the gas above the liquid. Henry's law has its most familiar applications in diving medicine, in which the increased pressure exerted on gases in the body at depth forces the gases into solution in the bloodstream. Rapid ascent from depth causes the gas to come out of solution within the bloodstream, resulting in decompression sickness or dysbarism. Henry's law does not carry the same weight in aviation medicine because the degree of change in atmospheric pressure per unit of distance is considerably less than the degree of change in water. Sudden decompression at high altitude similarly may result in dysbarism, however.

Additional Stresses of Flight

Other stresses of flight that can affect the patient or crew include temperature fluctuations, dehydration, noise, and vibration. Temperature changes may produce increases in metabolic rate and oxygen consumption. Prolonged exposure can result in motion sickness, disorientation, fatigue, and impaired performance.

As altitude increases and the air cools, the amount of moisture in the air decreases significantly. To prevent dehydration during AMT, fluid intake (oral or intravenous) must be monitored carefully, and all patients should receive humidified medical oxygen. Noise and vibration may represent the most ubiquitous stresses encountered in AMT; both may interfere with patient assessment or the function of medical equipment. Long-term exposure may result in fatigue, nausea, visual or vestibular disturbances, ear damage, and deterioration in task performance. Hearing protection should be worn during aircraft operations by the patient and crew.

PRINCIPLES OF AIR MEDICAL TRANSPORT SYSTEMS

Administrative Structure

Air medical services may take several forms. Despite a tremendous growth of independent (private) operations in the United States in recent years, the most common type of helicopter service remains the hospital-sponsored operation transporting patients from outlying referral centers or accident scenes to tertiary care centers. A single hospital or a consortium of institutions may sponsor these flight programs. In 2008, there were approximately 219 dedicated HEMS programs operating 668 helicopters—twice as many aircraft as there were in 1998. Single hospitals or consortiums accounted for 71% of the programs but only 50% of the helicopters; the remaining 50% of the helicopters were operated as independent (private) operations.[2] Public service agencies may also sponsor air medical services. Vehicles used by these programs are often multifunctional aircraft that serve in medical, search and rescue, fire suppression, and law enforcement roles. The Military Assistance to Safety and Traffic (MAST) program operated by the U.S. Armed Forces may transport ill or injured patients when no civilian service is available and when MAST aircraft, equipment, and personnel are not being used for the unit's primary military mission. Funded by tax dollars, these programs are often operated at no cost to the patient. In the United States, public-use and MAST helicopters account for more than 160 additional helicopters available for patient transport.[3]

There is no accurate accounting of the number of fixed-wing air ambulances companies or airplanes. Although some hospitals do sponsor fixed-wing AMT, it is more common for these programs to be private fee-for-service operations.

Types of Missions

Air medical missions may involve primary or secondary response. Primary responses ("scene flights") are responses in which the aircraft serves as the sole means of patient transport to a receiving facility. Aircraft involved in secondary responses—interfacility transport—move patients from outlying hospitals to facilities offering higher levels of care.

AMT missions may also be classified according to the level of care provided. This may include critical care transport, advanced life support, specialty care transport, or basic life support.

Air Medical Aircraft

Although the ground ambulance remains the primary means of out-of-hospital and interfacility patient transport, the use of the air ambulance has grown significantly since the 1970s. No one aircraft is ideal for the needs of all air medical programs or for all patients. The vehicle selected should meet the mission requirements of the program for the types of patients to be transported and the anticipated service area.

Helicopters (Rotor-Wing Aircraft)

The helicopter offers several advantages over other transport vehicles. Traveling "as the crow flies" at speeds of 120 to 180 mph, helicopter transport time is often 75% less than that

Figure 191-1. Confined spaces within helicopters may make performing procedures more challenging. (Photo courtesy of Ira Blumen, MD.)

for an equivalent distance by ground transport. The service area of helicopter programs is generally up to 150 to 200 miles from its base of operations. The rotor-wing aircraft has the ability to avoid common traffic delays and ground obstacles and can fly into locations that may be inaccessible to other modes of travel. Helicopter landing zone requirements are a disadvantage compared with ground ambulances but offer an advantage over the airport requirements of airplanes.

Disadvantages to rotor-wing flight include the presence of noise and turbulence, which may interfere with patient evaluation, monitoring, and management. Weather considerations may significantly limit the availability of helicopter transport. In small and medium-sized helicopters, cramped patient compartments and weight limitations (compared to ground ambulances) may limit the number of transport personnel or equipment that can be carried. Occasionally, this may compromise optimal patient care in the transport environment (Fig. 191-1).

Many helicopter programs permit flight only under visual flight rules. When the weather conditions (ceiling and visibility) fall below established program minimums, a program may decline to undertake a transport for safety reasons. However, an increasing number of programs are equipping their helicopters and training their pilots for instrument flight rules (IFR) to allow safe travel in less favorable weather conditions. With the aid of new technology, HEMS programs and hospitals are working together in many areas of the country to develop IFR approaches to private-use hospital helipads. IFR flight does not facilitate travel to the scene of an accident or to hospitals that are not equipped for an instrument approach.

Airplanes (Fixed-Wing Aircraft)

Although rotor-wing missions attract more media attention, fixed-wing flights constitute a significant portion of AMT operations. Fixed-wing aircraft provide increased range; greater speed; and often more patient, crew, and equipment capacity than do rotor-wing vehicles. Decreased cabin noise and turbulence create fewer patient management problems, and pressurization can combat the impact of physiologic gas laws. Fixed-wing operations are limited, however, to areas that have airports, runways of appropriate length or condition, and refueling facilities. During fixed-wing transports, patient transfers require multiple vehicles (i.e., hospital to ground ambulance to airplane).

Various fixed-wing aircraft are available for medical transport. These range from unpressurized light planes with single- or twin-piston engines to pressurized turboprops and jets. The selection of the ideal aircraft depends on the nature of the air medical mission.

Air Medical Flight Crew

Air medical crew members represent the broad spectrum of health care providers. AMT services that provide critical care transport, advanced life support, or specialty care transport must staff the vehicle with a minimum of two medical personnel to provide direct patient care.[4,5] Most AMT programs in the United States provide critical care transport teams composed of one registered nurse (RN) and an additional crew member. Some fixed-wing AMT services provide basic life support staff with a minimum of one certified/licensed emergency medical technician-basic (EMT-B).

For some AMT programs, crew configuration may be dependent on the mission (adult, pediatric, neonatal, or obstetrics). Data compiled from 1984 to 2005 show that the RN/paramedic team is most often used (>60%) in helicopter and airplane transports. Other combinations, including RN/RN (8%), RN/EMT, RN/physician, RN/respiratory therapist, and EMT-paramedic/EMT-paramedic, account for less than 5% each.[6]

Flight nurses generally have extensive experience in intensive care units or emergency departments. They may be specialized within the transport team to care for adult, pediatric, or neonatal patients. Paramedics often make their greatest contribution in the transport of critical patients from the scene of illness or injury. Respiratory therapists bring expertise in airway and ventilator management and oxygen delivery systems. Flight physicians may be residents, attending physicians, or medical directors of flight programs. Early research focused on the specific benefit of the onboard physician.[7-10] Although the answer to this question remains controversial, it is clear that the crew used by an AMT program must be explicitly tailored to the needs of the community and the patients it serves.

The AMT environment imposes unique considerations on the air medical flight crew that can influence their ability to provide patient care. Human factors work has shown that most medical care procedures are more difficult to perform in an AMT vehicle than in other ground-based settings.[11] Auscultation of the lungs, palpation of pulses, performance of cardiopulmonary resuscitation, endotracheal intubation, and recognition of visual alarms are all impaired while aloft.[12-15] In addition, fatigue, motion sickness, an erratic pattern of work activity, and the high risk involved in AMT operations may affect task performance significantly.[16]

Medical Direction

All air medical services require the active involvement of a physician as air medical director, who is responsible for supervising, evaluating, and ensuring the quality of medical care provided by the AMT team.[17] Emergency physicians play a significant role, with nearly 50% of all air medical directors having a background in emergency medicine.[18] The air medical director must have the final authority over all clinical aspects of the air medical service. The medical director should ensure that the medical personnel have adequate training and qualifications to deliver appropriate medical care, that appropriate medical equipment and supplies are available, and that the correct vehicle is selected for transport. Medical care policies and procedures should be established, including specific provisions for online and offline medical control. The Air Medical Physician Association and the National Association of EMS Physicians have established guidelines for the medical director of an air medical service.[19,20]

Safety

Safety is the predominant concern of air medical operations, and ensuring safe conduct is a fundamental part of every flight program.[21] Safety must also be an overriding consideration of medical and public safety personnel when considering the risks and benefits of AMT for every patient being transferred. Continual training of aircraft pilots and mechanics is essential, and both participate in ensuring the airworthiness of the vehicle. Medical personnel must be proficient in the emergency operations of the aircraft and the routine procedures in and around their helicopter or airplane. Crew fatigue and other self-imposed stresses that could affect safety, such as the use of prescription or over-the-counter medications, tobacco, and alcohol, must be scrupulously avoided.

Weather requirements or "minimums" must be strictly enforced. On receipt of a flight request, the pilot must verify the weather conditions and the condition of the aircraft. To ensure impartiality, the pilot should not be told of the patient's condition or acuity. The pilot always has the right to decline a mission because of aircraft or weather considerations. These decisions must not be influenced or reversed by administrators, flight crew, or other parties.

A practice that should be avoided with regard to helicopter transport and poor weather conditions is "helicopter shopping." The Federal Aviation Administration (FAA) has found that this dangerous operational practice has been a factor in several fatal HEMS accidents. *Helicopter shopping* refers to the practice of a requesting EMS agency or hospital calling numerous HEMS operators until one agrees to accept a flight—without disclosing with the accepting HEMS operator that other programs have declined the flight due to bad weather.[22,23] Although there may be circumstances in which a subsequent program can safely undertake and complete the flight, helicopter shopping can lead to an unsafe situation in which a program initiates a flight that it would have declined if it had been aware of all of the facts surrounding the request. In 2006, the FAA issued a letter to all state EMS directors describing helicopter shopping and requesting that they take action to prohibit this practice.[24]

Landing Zones

Helicopter landing zones are inherently dangerous places. The most obvious risk of injury is from impact with rotor blades. This danger is heightened during ground operations because the blades dip lowest to the ground at the slower rotor speeds associated with engine start-up and shutdown. Injuries also may occur as a result of debris being propelled through the air by "rotor wash," increased noise levels and an inability to hear warnings, and slippery surfaces found on exposed landing sites.

Many hospitals have designated landing areas that are appropriately lit and secured (Fig. 191-2), with fixed coordinates and predesignated liftoff and approach patterns. Most primary responses occur at unmarked sites, however. Ground personnel must be trained to designate and secure a safe landing zone for helicopter operations (Box 191-1). AMT programs have an obligation to help train ground staff on proper landing zone setup and conduct (Box 191-2).

Helicopter flights direct to the scene of an accident pose a unique risk to AMT due to potential hazards near the landing zone. This is especially true at night. In response to this, some out-of-hospital care providers and flight programs have found it beneficial and safer to utilize a rural or community hospital helipad to rendezvous. For some hospitals and emergency physicians, this has raised concerns regarding Emergency Medical Treatment and Active Labor Act (EMTALA) responsibilities to provide a medical screening exam for these patients. In May 2004, the Centers for Medicare and Medicaid Services (CMS) resolved this concern; CMS stated that the use of a helipad on hospital property that has a dedicated emergency department does not trigger EMTALA as long as the helipad is being used as a helistop for EMS personnel to rendezvous with air medical transport to complete the transport of a patient to a tertiary care or the closest appropriate facility.[25]

Figure 191-2. Landing zone safety is paramount to delivery of patients to hospitals. (Photo courtesy of Dan Lemkin, MD.)

Another adjunct to landing zone safety and night operations in general is the increasing utilization of Night Vision Goggles (NVG). A growing number of AMT programs are equipping their aircraft with NVGs and training their pilots and medical crews to use this sophisticated technology. NVGs dramtically magnify ambient light from the moon or stars to illuminate the ground, as well as natural terrain and man-made obstacles that could interfere with safe flight or landing.

Integration of AMT within Emergency Medical Service Systems

AMT should be an integral resource within a comprehensive EMS system. Integration begins with the establishment of geographic service areas. Service areas may be determined based on program mission description, aircraft range and speed, the placement of specialty centers and receiving facilities, and the location and mission of air medical programs in adjacent regions. Population densities are also key factors. Helicopters are generally less useful in urban settings because of the proximity of health care facilities and a lack of open and safe landing zones. Paramedics, EMTs, and other public safety personnel should be provided with guidelines specifying when AMT should be considered. These protocols are best developed by EMS medical directors in close collaboration with their air medical colleagues.

■ CLINICAL CONCEPTS AND PATIENT CARE

Although virtually all types of patients have been transported by air medical services, definitive prospective data indicating which patients will benefit from flight are lacking. Many ques-

BOX 191-1 Safety of Personnel Approaching and Disembarking a Helicopter

- Vehicles and personnel should be kept at least 100 ft from the landing zone.
- Spectators should be kept at least 200 ft from the landing zone.
- No smoking or running is permitted within 50 ft of the helicopter.
- All items (e.g., IV lines, poles) should be kept below shoulder height.
- The flight crew opens and closes aircraft doors.
- The flight crew directs and supervises the loading and unloading of the patient and equipment.
- Ground personnel should use eye and ear protection.
- Approach the helicopter *only* when signaled to do so by the pilot or an onboard crew member.
- Approach and depart the helicopter *only* forward of the rear cabin door and in a crouched position with your head down.
- *Never approach or depart from the rear of the helicopter.*
- Stay clear of the tail rotor; it is virtually invisible and extremely dangerous.
- If the aircraft is parked on a slope, approach and depart on the downhill side (greatest clearance under the blades).
- Keep the landing zone clear of (or hold on to) all loose articles (e.g., hats, scarves, sheets, pillows).
- Protect patient from the dust and debris.
- Follow the flight crew's instructions at all times.
- In disaster situations and mass casualty incidents, victims, witnesses, and spectators may become hysterical or exhibit signs of an acute situational reaction. These individuals must be kept clear of the landing zone and helicopter *at all times*. Injured victims who exhibit this behavior should *not* be triaged for helicopter transport, or they should be transported *only* with adequate physical or chemical restraints in use.
- *If you do not know, ask.*

Courtesy of University of Chicago Aeromedical Network (UCAN), University of Chicago Medical Center, and Illinois Association of Air and Critical Care Transport (IAACCT), 2008.

BOX 191-2 Landing Zone (LZ) Requirements for Air Medical Transport

Landing Area
- LZ should be as close as possible to the scene or hospital entrance, but not so close that it may interfere with ground operations or patient care.
- LZ should be at least 100 × 100 ft.
- LZ should be as flat and level as possible.
- LZ *must* be clear of debris.

Hazards and Obstructions
- Identify all potential hazards that may be on the ground or near the approach/departure path of LZ.
- LZ should be clear of wires, poles, trees, buildings, vehicles, and spectators.
- Road cones, ropes, tape, and barricades are *not* recommended for use near LZ.
- Perimeter of LZ should be at least 50 ft away from potential obstructions and hazards.
- LZ should be located *upwind* from any hazardous material incident.

Approach and Departure Path
- Path should point into the wind and be free of obstruction to an altitude of 500 ft above the surface.
- Path should *not* pass over command posts, treatment areas, or operationally congested areas on the ground.

Day Operations
- Use radio communications and hand signals.
- Stand with your back to the wind.

Night Operations
- Use radio communications and lighting to designate LZ.
- Spotlights should be directed at the top of possible hazards, *not* toward the approaching or departing aircraft.
- Position a portable light, vehicle headlights, emergency vehicle flashing lights, flare, or chemical stick at each corner, with a fifth light upwind.
- Nonessential lights should be turned off.

Light Sources
- Lights *must* be clear of LZ.
- If portable, lights *must* be well secured.
- *Never* point lights toward an approaching or departing helicopter.

Wind Indicator
- Indicator may be a wind sock, flag, flare, or smoke.
- Indicator *must* be clear of LZ.
- If portable, indicator *must* be well secured.

Courtesy of University of Chicago Aeromedical Network (UCAN), University of Chicago Medical Center, and Illinois Association of Air and Critical Care Transport (IAACCT), 2008.

tions regarding the triage of patients to air or ground transport, the efficacy of air medical care, and the effects of AMT on morbidity and mortality in medical and surgical conditions remain unanswered. In an effort to ensure that AMT resources are used wisely, the Air Medical Physician Association has established a detailed medical condition list for the appropriate use of AMT.[26] A more general approach to the need for AMT is illustrated in Box 191-3.

Trauma

Although there are some analyses of HEMS use for secondary (interfacility) missions, the vast majority of trauma studies have addressed air medical utilization for scene response.[27–29] There are data from Pennsylvania and California brain-injured patients undergoing out-of-hospital intubation demonstrating HEMS-associated improvements in both morbidity and mortality in patients with traumatic brain injury.[30,31]

Methodologic heterogeneity precludes formal meta-analysis of the AMT outcomes data. However, in considering the mortality benefit that appears to be associated with HEMS, existing data support an estimate of 20 to 35% survival improvement, or the saving of three to six lives (perhaps fewer for pediatric patients) per 100 air medical trauma flights.[32-39] Furthermore, trauma systems experts' finding that HEMS represents the *only* modality by which nearly 28% of U.S. residents have timely (i.e., within 1 hour) access to level I or II trauma centers emphasizes the vital role of AMT in care of the injured patient.[40] Studies have also presented data that suggest lack of HEMS benefit, but these studies are a small minority and are limited by confounding and methodologic quirks such as inclusion of a preponderance of transports to nontrauma centers.[41,42]

On the other hand, seminal work in HEMS casts doubt on the supposed logistical advantages of helicopter dispatch.[43] Faster times to trauma centers are not required for air medical accrual of outcomes benefit. Studies conducted from regions as disparate as California and The Netherlands demonstrate HEMS mortality benefit but find similar scene-to-trauma center times for ground and air transports.[39,44] Even so, it seems clear that for many patients, factors other than speed are responsible for AMT's benefits.

AMT is unlikely to improve outcome in those whose injuries are either trivial or grave. For instance, if the Injury Severity Score's 75-point scale is collapsed into five ordinal categories, analysis finds a significant association between helicopter transport and improved mortality in the middle three categories (survival odds ratios range from 2.1 to 2.6).[45,46]

BOX 191-3 CRITERIA FOR AIR MEDICAL TRANSPORT (AMT)

1. Distance to the closest appropriate facility is too great for safe and timely transport by ground ambulance.
2. Patient's clinical condition requires that the time spent in transport be as short as possible.
3. Patient's condition is time critical, requiring specific or timely treatment not available at the referring hospital.
4. Potential for transport delay associated with ground transport is likely to worsen the patient's clinical condition.
5. Patient requires critical care life support during transport that was not available from the local ground ambulance service.
6. Patient is located in an area inaccessible to regular ground traffic, impeding ambulance egress or access.
7. Local ground units are not available for long-distance transport.
8. Use of local ground transport services would leave the local area without adequate EMS coverage.
9. For interfacility medical transport, the requesting physician based on his/her best medical judgment and information available at that time of transport determined the need for AMT.
10. For scene medical transport, the requesting authorized out-of-hospital provider based on applicable policy, his/her best medical judgment and information available at that time of transport determined the need for AMT.

Courtesy of University of Chicago Aeromedical Network (UCAN), University of Chicago Medical Center, 2008. Based on Association of Air Medical Services: Position paper on the appropriate use of emergency air medical services. J Air Med Transport 9:29, 1990; and Determination of Medical Necessity for Air and Critical Care Medical Transportation. Position Statement of the Air Medical Physician Association. Revised April 13, 2002. In Blumen IJ (ed): Principles and Direction in Air Medical Transport. Salt Lake City, Utah, Air Medical Physician Association, 2006.

Cardiac Disorders

The ability to study HEMS-related outcomes benefit in acute coronary syndrome is limited by the lack of validated scores that can be used to stratify risk and predict outcome. There are data demonstrating the use of helicopter transport to extend the ability of primary angioplasty centers, with outcomes of patients flown from a distance equaling outcomes of patients presenting primarily to the cardiac referral center.[47,48]

Although HEMS could conceivably shorten door to percutaneous coronary intervention (PCI) time by transporting patients rapidly from hospitals without PCI capability to a referral center, in some circumstances the patient will be best served by receiving thrombolytic therapy in the sending hospital and then being transported by the most appropriate mode of transport (air or ground ambulance). In other situations, however, pre-hospital and interfacility helicopter transport can play an important contributory role in extending regional cardiac care systems and primary PCI to many patients.

Stroke

With the advent of time-critical therapy for ischemic stroke, HEMS has played an increasing role in the regionalization of acute neurologic care. Early studies demonstrating safety of transport of post-thrombolysis stroke patients have been complemented by case series illustrating the increasing use of helicopter interfacility transport for stroke.[49,50] However, once a patient has received thrombolysis, the risk-benefit analysis for air versus ground transport may be altered. For many patients, ground ambulance transport will be appropriate. For other patients, however, the referring physician may determine that AMT is still warranted. Case reports and series have demonstrated the utility of air medical dispatch for primary (scene) transport of patients with strong suspicion of stroke.[51-53] In one region, ground EMS providers were able to identify stroke with accuracy (nearly four out of five air-transported patients had the diagnosis confirmed), and helicopter-transported patients comprised nearly one fourth of the stroke center's thrombolysis volume.[52] The use of strict triage definitions keeps inappropriate calls for AMT to acceptably low levels while allowing for a significant extension of the geography served by an individual stroke center.[52]

Pregnancy

With appropriate triage, obstetric air transport can counterbalance risks of delivering an infant in a helicopter's confined space, with benefits of transporting a high-risk pregnancy in the prepartum phase.[54] Series demonstrate that with helicopter transport, high-risk obstetric patients (and their subsequently born neonates) from distant hospitals have outcomes as good as those presenting primarily to the obstetric referral center.[54,55]

Neonates and Children

The use of AMT to extend the reach of neonatal care centers is reported from many settings.[56,57] The most rigorous analysis suggests that long-distance AMT allows for infants from remote areas to achieve outcomes as good as those achieved with infants born in urban centers. Although neonates are vulnerable to physiologic deterioration, air transport is associated with no more derangement in oxygenation and ventilation than is transport (with the same team) by ground vehicle.[56]

Many areas depend on AMT to deliver critically ill or injured children to regional pediatric centers. Although speed of transport may be an important consideration, the emphasis is often more on the transport *team* than on the *mode* of transport. Experienced pediatric transfer teams often bring a level of expertise unavailable to the pediatric patient in the outlying hospital.[58] Appropriate training, experience, and competency are essential for those responsible for the transport of critically ill or injured children.[59] Depending on regional AMT and pediatric resources, the transport team may be a regularly scheduled transport team or a pediatric specialty team. Several studies have compared pediatric transports conducted by specialty pediatric teams versus regularly scheduled transport teams. Specialized pediatric transport teams, including services providing extracorporeal membrane oxygenation, were found to have comparable outcomes and fewer adverse events.[60-62]

EFFICACY AND COST-EFFECTIVENESS

Cost-benefit is deservedly an area of increasing focus for AMT. Part of the problem lies in the imperfections of current triage (e.g., for trauma) and the inability to precisely identify, in prospective manner, which patients will truly benefit from helicopter EMS. However, it is equally true that in some regions there is little, if any, guidance regarding when air medical dispatch is indicated.[63] Using endorsed guidelines for air medical dispatch, EMS regional authorities should collaborate to generate criteria best for their own systems, with constant refinement as indicated by rigorous utilization review.[64]

Fortunately, compared to the cost-benefit ratios of widely accepted medical interventions, AMT is well within the accepted range per quality-adjusted life-year saved.[65-68] One Scandinavian study, with a large proportion of rural transports, concluded, "The analysis indicates that the benefits of ambulance missions flown by helicopters exceeds the costs by a factor of almost six."[69] Another group from the region estimates that HEMS contributes to the cost-effectiveness of primary PCI; even when patients were transported from longer distances (and by air), the cost-effectiveness of primary PCI over time is maintained.[70] Other investigators have demonstrated the favorable cost-effectiveness of helicopter stroke transports.[71]

Cost-effectiveness determinations are not straightforward. It is difficult to calculate true cost-effectiveness for helicopter use for transports that would otherwise not occur (as with high-risk obstetrics cases)[54] or would deliver patients outside critical time windows (as for stroke or cardiac transports).[49,72] There is no ground transport option capable of rapidly moving through rush hour traffic in Los Angeles or getting patients from coastal islands to neurointerventional or cardiac catheterization suites.[49,54] Because HEMS represents the only mechanism by which more than 80 million U.S. citizens have timely access to mortality-improving high-level trauma center care,[73] it is obvious that some form of air transport is a "must-have" for some U.S. EMS regions. The direct bearing on the cost-effectiveness calculations is not difficult to understand: If a region must have air medical assets for some group, then it is most reasonable to amortize the "overhead" costs across all transported patients.

Also, air transport costs should be compared with those of the real-life alternative mode of transport. In many cases, AMT is arguably less expensive than the alternative.[74] Unfortunately, the job of assessing HEMS' cost-effectiveness is rendered difficult by the extremely limited amount of information on cost-effectiveness of ground EMS.[75] Crew and patient safety are issues in both air and ground systems.

FUTURE OF AIR MEDICAL TRANSPORT

AMT faces many challenges. The dramatic increase in the number of medical helicopters in the United States since the late 1990s has heightened concerns for their inappropriate use. AMT services work best when they are integral to and enhance an overall system of out-of-hospital care and interfacility transport. Systems must be in place to educate requesting agencies and professionals regarding the appropriate use of available air and ground resources. At the same time, flight programs must be more vigilant in terms of triage. It also seems that advances in ground-based EMS and the availability of critical care ground ambulances for interfacility transports are offsetting many of the assumed benefits of AMT. However, geographic issues, the regionalization of specialty services, the development of new highly time-sensitive therapies, and the need to transport patients quickly over long distances will require that there be systems in place to continually assess the potential value of initiating or continuing AMT.

Research into these issues is a key facet of the future of AMT. The challenge with HEMS and outcomes research is not *whether* but, rather, *in whom* there is benefit. Currently, the major dilemma facing helicopter transport outcomes researchers is the identification of triage variables that can prospectively (i.e., at the time of transport vehicle selection) guide utilization of the air medical resource.[63,64,76]

Safety must be the priority in AMT. AMT programs, aviation operators, air medical associations, and regulatory agencies continue to address this issue. However, it is important to remember the significant role that requesting and receiving personnel can also play with regard to AMT safety and the safe transport of their patients.

The references for this chapter can be found online by accessing the accompanying Expert Consult website.