Air Medical Transport

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Emergency air medical transport has become an integral part of the practice of medicine. In 1990, there were more than 170 air medical programs in operation in the United States. The proper and safe use of air medical transport requires a basic understanding of the medical implications of flight and the capabilities and constraints involved in transporting patients by air. The purpose of this paper is to review this information and provide guidelines for the use of air medical transport.

Key words. Aircraft; transportation of patients; emergency medical service; altitude.
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The marriage of aviation and medicine has expanded the reach of critical care units and other specialized care units beyond the local hospital setting. The incorporation of monitors, ventilators, oxygen and suction, infusion pumps, etc, allows critical care delivery in the air.[1] With increased availability of air medical transport, we have seen a rise in the number of critically ill or injured patients transported by air for definitive care at regional centers.[2] Physicians of all specialties are likely to send or receive patients by air medical transport (AMT) at some point in their practice.

Unfortunately, many advertised "air ambulance" services are nothing more than business aircraft staffed by moonlighting paramedics or nurses employed on an ad hoc basis by a charter aircraft company.[2] There may be no medical direction at all and thus no practice standards, appropriate education of personnel, quality assurance, or medical control.

The proper and safe use of air medical transport requires a basic understanding of the medical implications of flight and the constraints of the air medical environment. It is the purpose of this paper to review these issues and provide the physician unfamiliar with AMT with guidelines for its use.

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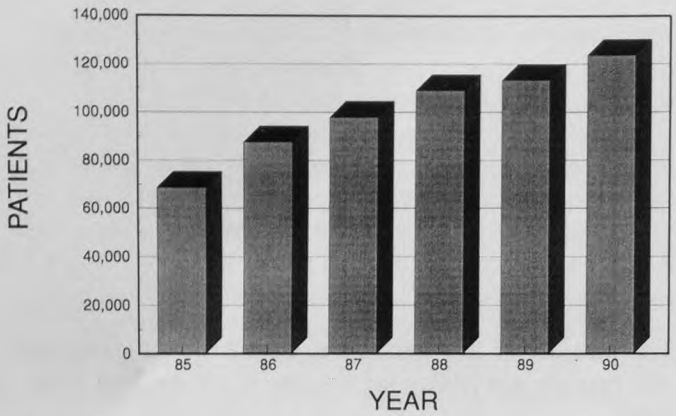
History of Air Medical Transport

As early as 1784, after the balloon flight demonstrations of the Montgolfier brothers, physicians began to consider the benefits their patients might gain from flight. Jean-François Picot theorized that patients not only could tolerate balloon flight, but would in fact benefit from purer air encountered at higher altitudes.[3] Although many believed the advent of AMT occurred during the siege of Paris (1870), the romantic notion that seriously ill or injured patients were moved by balloon from that city is historically inaccurate.[3]

Air medical transport using heavier-than-air machines was initiated in 1909, when Captain George Gosman built a plane specifically for this purpose.[4] However, the plane was never used to transport patients. In 1917, the French Dorand AR II was the first air ambulance that actually carried patients. World War II saw great increases in the use of AMT. It is estimated that more than one million patients were airlifted by the United States from all theaters of conflict with an overall death rate of only 4/100,000.[3,5]

The Korean war brought new challenges and opportunities for AMT. In 1950, the use of the helicopter for the front-line medical evacuation of patients during combat was authorized.[3] More than 17,000 patients were transported by army helicopters alone from January 1951 to January 1953.

The outstanding medical evacuation system developed during the war in Vietnam owed much to the experience gained during the Korean conflict. The effective use of helicopters for AMT in Vietnam, and their appearance almost nightly on television, kindled interest in AMT use for the civilian population.



Patients transported by civilian air medical programs, by year.

At approximately the same time, interest in improving care in the civilian prehospital arena arose, and services previously available only in the hospital were delivered in the field by ambulances staffed by health care workers.[6] It was not long before these expanded medical services were combined with the helicopter to provide the first United States AMT capability. Since that time, AMT in the civilian sector has developed rapidly.

In 1979 there were more than 500 charter aircraft companies that performed air ambulance missions in the continental United States, and over 200 that provided this service in Alaska alone. In 1990 there were more than 170 air-medical programs in operation in the United States.[7] The number of air medical transports has increased dramatically since 1985 (Figure).

Types of Air Medical Transport

In general, AMT can be divided in two broad categories: fixed-wing (airplane) AMT and rotor-wing (helicopter) AMT. These two types of AMT have many characteristics in common. The deciding factor in choosing one over the other generally relates to efficiency. Fixed-wing AMT tends to be a more efficient process for patients who must be transported over a distance of more than 200 to 250 miles. For shorter transports, helicopter AMT is routinely used. Both these modes of AMT are substantially more expensive than ground transportation and add an element of risk not present in ground transportation. Therefore, the decision to use AMT should be based on the belief that some special attribute of AMT is important in the care of a particular patient.

Attributes of Helicopter Transport

Speed. Modern helicopters routinely used in medical missions are capable of sustained speeds in excess of 150 mph.[2] This, plus the ability to move point to point, may translate into a saving of time over other forms of patient transport. Interestingly, this attribute has led some investigators to determine optimal distances for helicopter use based on transport time.[8]

Accessibility. Vertical takeoff and landing capabilities permit evacuation of patients from areas inaccessible to other transport vehicles. Injuries that occur during mountaineering or excursions into wilderness areas are good examples.

Specialized personnel and technology. Air medical services are usually based at tertiary care centers and are staffed with highly skilled and trained personnel. They are routinely equipped with sophisticated medical technology and bring their advanced capabilities to patients across a wide geographic area.

These attributes of helicopter AMT should be the basis for considering this particular mode of transportation over ground transport. If these characteristics are not important, then this expensive transport mode is not appropriate.

Attributes of Fixed-Wing Transport

Speed. Even the simplest of fixed-wing aircraft is capable of speeds unobtainable by ground vehicles. Modern jet aircraft can travel several hundreds of miles per hour.[2] The restriction of these aircraft to airports for takeoff and landing, however, generally makes their use impractical for distances less than 200 miles.

Specialized personnel and equipment. Like the helicopter air ambulance, fixed-wing aircraft may be equipped with specialized medical devices and highly trained personnel appropriate to the patient's needs. In general, however, the cabins of airplanes used in AMT are substantially larger than those in air medical helicopters, and noise and vibration characteristics are more conducive to patient monitoring, patient care, and comfort.

Characteristics of rotor-wing and fixed-wing AMT are compared in the table. It should be recognized that ground transport of patients is less expensive, may actually be quicker in some situations, is likely to be safer than AMT, and is more universally available. Therefore, ground transport should be the first mode considered in every transport situation.

Selecting an Air Medical Transport Company

The physician faced with selecting an air medical transport service may have difficulty judging the quality of the

Characteristics of Rotor-Wing and Fixed-Wing Aircraft

Characteristic	Helicopter	Fixed-Wing
Relative cost compared with ground transportation	Expensive	Expensive
Speed (knots)	100 to 150	200 to >400
Accessibility	Point to point	Requires runway
Range (nautical miles)	300 to 400	May be >2700
Safety	Questionable	Relatively safe
Cabin size	Small	Large
Noise and vibration	Significant with possible negative impact on patient care	Minimal with limited impact on patient care

service provided. For helicopter programs that are hospital based, membership in the Association of Air Medical Services (AAMS) generally signifies a commitment to quality. The recently organized Commission for Accreditation of Air Medical Services spawned by AAMS may in the future identify quality organizations. Fixed-wing transport services may also be members of AAMS or the Professional Air Transport Association or both.

The following are useful points to consider in evaluating an AMT service:

- The qualifications of the medical director
- The composition, training, and certification of the medical flight crew
- The safety record of the aircraft vendor
- The experience of the pilot and crew members.

For any particular patient flight, the physician should ensure that appropriate equipment and medical personnel will be used.

Aircraft Ambiance

Aviation remains a competitive industry, and the air ambulance component is no exception. Unfortunately, most aircraft used in civilian AMT were not specifically designed with this purpose in mind. Therefore, some compromises are required to provide patient care in the aircraft environment. Furthermore, the aviation environment poses additional stresses on the patient, the caregiver, and medical equipment.[9] The magnitude of these factors is greatest in fixed-wing operations and of less concern in helicopter transport.

Oxygen. Hypoxemia is the single greatest threat to anyone who flies. Physiologic effects of hypoxemia can be detected in healthy persons even at altitudes of less than 10,000 feet.[9] Hypoxemia increases as altitude increases and ambient pressure falls. Cabin pressurization minimizes this problem in many airplanes, but patients with impaired pulmonary function may be at risk for hypoxemia at "cabin altitudes" (ie, ambient pressure) commonly achieved in pressurized craft. Adjusting the fraction of inspired oxygen to maintain the inspired partial pressure of oxygen constant throughout the flight profile is a clinically useful technique.[9] The widespread availability of pulse oximeters has lessened the incidence of sustained hypoxemia during AMT by permitting early recognition. Helicopters usually do not exceed an altitude of 1000 feet above surface elevation, and thus hypoxemia secondary to decreased ambient pressure is of less concern.

Acceleration. The occupants of a fixed-wing aircraft as it is accelerated down the runway, or of a helicopter lifting off, experience a change in velocity and thus acceleration. Acceleration is a vector quantity, having both magnitude and direction. For this reason, the patient should be positioned so as to limit the stress induced by sustained acceleration.[9] The acceleration force experienced in a helicopter during routine operation tends to be of low magnitude and similar to that encountered in ground transport vehicles.

Gas volumes. Ambient pressure decreases as altitude increases. Changes in pressure with changing altitude may affect a number of medical devices as well as the patient. Contrary to common belief, cabin pressurization does not eliminate this concern. Pressurization does permit comfortable flight at altitudes that could not be attained without it, but generally does not result in a cabin altitude equivalent to sea level. Cabin altitudes of 7000 to 8000 feet are typical, and thus, the equipment and patient will be exposed to some pressure change. Any gas-filled structure therefore becomes of concern. Air

trapped in a patient's sinuses, for example, may expand and cause discomfort. Similarly, monitoring devices that have air-filled cuffs may malfunction or injure the patient with changing altitude.

Humidity. Humidity is of particular concern in fixed-wing operations because cabin air is taken from the ambient atmosphere, even in pressurized aircraft. When warmed, this air becomes very dry and may lead to drying of the patient's secretions and resultant discomfort during flight.[9]

Noise. Modern aircraft produce substantial noise. The cabins of most airplanes are quiet enough for conversation and patient evaluation, but the cabins of helicopters are so loud as to preclude auscultation of the lungs. Thus, protective headphones and intercom systems are needed.

Vibration. The two major sources of vibration during AMT are the power plant (engines and propellers or blades) and turbulence from air in which the aircraft is traveling. In addition to causing patient fatigue and discomfort, vibrations may also cause monitoring errors and malfunctions of medical equipment.[9]

The Transport Team

Only a minority of medical flight crews include physicians. Most helicopter transport teams include a registered nurse. There is considerable controversy over whether the presence of physicians during AMT improves patient outcome. For example, physician intervention on AMT has not been proven to improve the rate of mortality after a traumatic cardiac arrest.[10] Snow et al retrospectively studied the need for physician presence during 295 physician-manned helicopter flights and concluded that in only 25% of these flights was a physician actually necessary.[11] Data on the need for physicians during fixed-wing transports are lacking.

Because the needs of patients differ, a flight crew appropriate to the needs of the particular patient being transported should be selected before transport.

Safety

Aviation aspects. Air medical rotor-wing aircraft have an alarming history of crashing, with resultant morbidity and mortality.[12] In 1986, 14 emergency medical service (EMS) helicopter accidents occurred, destroying or substantially damaging 9% of the country's air medical helicopter fleet.[2] The National Transportation Safety Board (NTSB) subsequently undertook a safety study of helicopter air-ambulance operations and concluded that poor weather poses the greatest single hazard to EMS helicopter operations.[13]

Since publication of the NTSB study, significant improvement in helicopter air-ambulance accident rates has occurred.[14] The AAMS, which was established more than a decade ago, has encouraged appropriate medical direction through its quality standards and more recently through its program of accreditation and establishment of the independent accrediting commission mentioned earlier. Safety studies of fixed-wing transports are not reported, although aggregate commercial transport data would suggest that fixed-wing transport is associated with fewer accidents.

It is our firm belief that aviation professionals are the only ones qualified to make aviation decisions. We isolate our pilot team from patient information before departure so that they may make a "go/no go" judgment based on aeronautical considerations alone. The final authority as to the operation of any aircraft, per federal air aviation regulations, rests with the pilot in command, and the medical personnel should respect and defer to this authority.

Medical aspects. For some medical conditions, it is known that AMT can be accomplished with minimal risk. For example, persons suffering acute myocardial infarction (MI) may benefit from emergency thrombolytic therapy, angioplasty, and other interventions. To receive many of these therapies, MI patients may require emergency transfer to one of the 10% of hospitals that provide the full spectrum of interventional services.[15] A number of case series that involved acute MI patients have demonstrated a low incidence of complications occurring during AMT.[15,16] A current study of transported and nontransported acute MI patients who received thrombolytic therapy demonstrated no increase in the incidence of bleeding complications, mortality, or other adverse effects attributable to AMT.[17]

Medical complications secondary to factors intrinsic to flight have been reported. For example, dysfunction of activity-sensing pacemakers has been reported to be caused by the effect of rotor motion and flight vibration during AMT.[18,19] Despite the problems associated with flight, many medical procedures can be safely performed in the air.[20]

When to Use Air Medical Transport

Air medical transport is generally used in two situations: rescue and urgent interhospital transfer. Rescue operations with helicopters to scenes of accidents and illness are commonly requested by public safety personnel. Like all AMT, the decision to use this expensive and poten-

tially dangerous mode of transport should be based on the perceived need for the speed, accessibility, or specialized equipment and personnel that it provides. Most helicopter transport programs have developed policies and procedures with triage criteria for helicopter use. Fixed-wing rescue operations are unusual because landing facilities are required, but these may occur in remote regions.

Urgent interhospital AMT generally should be reserved for those patients who are critically or seriously ill and require interventions or specialized care unavailable at the referring hospital.[21] The benefit of receiving this specialized care must be weighed against the risk of transport. In many instances the decision that transport is required is easy, as in the case of the patient requiring neurosurgical intervention where no neurosurgeon is available locally. At other times these decisions may be quite difficult. General guidelines are available for specific illness categories. The American College of Surgeons committee on trauma, through its Advanced Trauma Life Support course, has developed recommendations for determining the need for interhospital transport of critically ill patients to specialized trauma centers. These include:

- A Glasgow Coma Scale score of less than 10, or a falling Glasgow Coma Scale score
- Penetrating neurologic injuries or depressed skull fractures, or patients with lateralizing neurologic signs
- Suspected cardiac or intrathoracic vascular injuries or major chest wall trauma
- Patients at the extremes of age (younger than 5 or older than 55 years of age) or those with known preexisting physiological impairments (eg, cardiorespiratory disease).

Organized rules covering the spectrum of nontraumatic surgical illness or medical conditions are difficult to establish. In the final analysis, the decision to transfer a critically ill patient by air rests on some assessment of the benefits gained from the transfer and the associated risks. While air transport offers many benefits, liabilities associated with AMT should also be considered in deciding to use AMT instead of ground transport.

Preparing the Patient for Transport

The preparation of the patient for air medical transport must, of course, begin with stabilizing the patient's medical condition using appropriate medical measures, whether in rescue mode or for interhospital transport. Added to the generally applicable concerns regarding patient management are the forces acting on the patient in flight and the difficulties of detecting and treating complications in the aircraft. Patients with a high potential for loss of airway should be intubated in a controlled manner before flight. For interhospital transport, contact with the receiving physician and institution is an early priority. Physician-to-physician contact is necessary to ensure that appropriate information is exchanged and to optimize patient care before and during transport. Patients being transported by air should be evaluated with the effects of pressure and other forces within the aviation environment in mind. Closed gas spaces should be decompressed. Nasogastric decompression and urinary catheter insertion should be considered if they have not already been done, as these procedures may contribute significantly to patient comfort. Traction devices using hanging weights may cause serious injury or discomfort to the patient during the accelerations of the transport; therefore, other methods of stabilization should be used. Fresh circumferential casts should be bivalved to prevent vascular compromise from continued swelling, particularly during prolonged transports. A discussion of the patient's condition and current therapy with the transport team or service will often result in additional recommendations for optimum patient comfort and safety during transport.

The logistics of AMT are an important component of transport preparation. Good communication is the key to a successful transport, whether during rescue operations or during interfacility transfers. Ground transport units ideally will have radio communications with the aircraft and should remain at the point of takeoff for a time after departure in case an unexpected deterioration in the patient's condition or an aircraft malfunction makes a return to the ground advisable.

Legal Requirements for Interhospital Transfers

The "dumping" of patients on public hospitals was one of the major stimuli that resulted in the writing and subsequent enactment in 1986 of the Consolidated Omnibus Reconciliation Act (COBRA) of 1985 with its section "Special Responsibilities of Hospitals in Emergency Cases." This law as amended has important implications for AMT, as it specifies certain requirements for legal interhospital transfers. The law requires that the transferring hospital provide treatment within its capacity to minimize the risk to the patient. The transferring hospital must secure an accepting physician at a facility that has space and personnel appropriate to the patient's

needs. Under the provisions of COBRA, the transferring hospital is responsible for ensuring that the transfer ". . . is effected through qualified personnel and transportation equipment, as required, including the use of necessary and medically appropriate life support measures during transfer. . . ." Penalties for violation of COBRA are severe and include fines of up to $50,000 for each violation for both physicians and hospitals and exclusion from Medicare and state health programs.

Reimbursement

For many years, hospital helicopter transport program charges have not reflected true operating costs.[2] Patient revenue from other hospital charges has been used to offset operating losses. Charges for helicopter transport continue to rise, with an average 100-mile round-trip mission costing in excess of $2000 in 1990.[2] This figure represents a 40% increase over the average cost of a similar trip reported in 1989.

In many instances, patient transport charges are unpaid. Unfortunately, the "dumping" of patients on hospitals by AMT services may lead to ethical, legal, professional, and regulatory dilemmas for emergency medicine professionals and health care institutions. To control this problem, it has been suggested that institutional policies for helicopter AMT of severely injured or ill patients should be established, without regard to the patient's payer class.[22,23] These policies may also prevent the transport of patients by helicopter who would be more appropriately transported by ground. Helicopter transport programs are dramatic and glamorous. Their benefit to the patient remains an area of controversy but their public relations benefit to the hospital is clear. Wasting health care resources and subjecting patients to the risks of helicopter for public relations value is unacceptable.

Fixed-wing operations are generally conducted in a nonemergent fashion. It is general practice across the country to refuse to perform fixed-wing transport at a loss and to require payment at the time of the service.

Conclusions

Emergency air medical systems have become an integral part of the practice of critical care medicine. These systems provide specialized care for the severely injured and ill, and thus may be needed for patients of health care practitioners of all types. Understanding the medical implications of flight and how flying and its environment affect patients and medical equipment will help the physician use these resources in a safe and appropriate manner.

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