Principles and Direction of Air Medical Transport

HISTORY OF AIR MEDICAL TRANSPORT

Jack B. Davidoff, MD, EMT-P

INTRODUCTION

From the beginning of our existence, human kind has been exposed to elements and forces that can cause illness, injury or worse. Prior to the emergence of individuals who learned to care for the sick and injured, many people succumbed to even minor illness or injury. While everyday existence puts us in a battle with these forces, nothing can compare to the numbers and severity of injured and ill as seen during times of war. Hence it is not surprising that much of our knowledge and therefore technology and procedures has been learned and evaluated during major wars.

EARLY MILITARY EXPERIENCE

Early statistics showed the importance of rapidly transporting and caring for the injured and ill. During World War I, the average time from injury to care was 12 to 18 hours; the death rate of these injured was 8.5%. Although this was an improvement from early battles, it was not acceptable. During the Korean Conflict, injured troops were transported much more rapidly in most cases, many times by helicopter; and the mortality rate dropped to 2.2%. During the Vietnam War, Operation Dust-Off, which utilized helicopters and trained medics, flew nearly 1 million injured patients, reducing the wound-to-care time to an average of 65 minutes and the mortality rate dropped to 1%. This was a noticeable drop in mortality rates that was at least partially attributed to the use of helicopters. It significantly helped lead the way for civilian air medicine.

Prior to 1792, most injured or ill persons had been cared for by themselves and/or family. During the fifteenth century, Queen Isabella of Spain coined the term “ambulance,” referring to field hospitals and tents to care for the wounded.

In 1792, Baron Dominique-Jean Larrey, who was Napoleon Bonaparte’s Chief Surgeon, developed a legion of 340 men, which included 3 divisions of 113 each. Each division had 12 light and 4 heavy carriages. These carriages had been designed by Larrey after observing the carriages used to carry the army artillery. Larrey noted that the artillery could be moved quickly so that it would not be captured by the opposing army. Larrey felt that rapidly transporting injured troops would boost morale and make them fight better. He called these vehicles “ambulance volante” or “flying ambulances.” Baron F. P. Percy was another French military surgeon who worked with Larrey. Percy invented the first litter and actually trained soldiers to care for the wounded.

AIR MEDICAL TRANSPORT — THE EARLY YEARS

Although the use of the aircraft for transporting patients became known to many by watching the TV show MASH, some references link its beginning to the Franco-Prussian War (1870-1871), when nearly 160 wounded French soldiers were airlifted using observation balloons from Paris which was under siege. This, however, has been disputed by others, who claim that the individuals airlifted were not injured, but were merely trying to escape the conflict.

Although they did not know it at the time, the Wright brothers changed the world and certainly the history of air medical transport with their 59 second flight on December 17, 1903.

As World War I began, there were attempts to utilize airplanes as ambulances. The French Air Services evacuated some soldiers from Serbia as early as 1915.1 As the United States began preparing for this First World War, thousands of new pilots were trained in rural airfields throughout the US. Many suffered injuries and required transport to hospitals that were hours away by ambulance. In 1918, Captain William C. Ocker converted an IN-4 “Jenny” to accommodate a patient in a semi-recumbent litter in the rear cockpit. This was the first recorded US military air ambulance. Eight years earlier, two US Army medical officers, Capt George H. R. Grosman and Lt. A. L. Rhodes, designed an airplane to transport patients. They used their own money and attempted to fly this aircraft at Fort Barrancas, Florida. Unfortunately, on its first test flight it flew only 500 feet at an altitude of 100 feet before crashing. They were unsuccessful in obtaining official backing for the project. The concept was forgotten for a short time.

In 1925 the United States Army Air Corps was formed. This group’s mission was to provide rapid medical care and transportation of wounded troops. Their aircraft were aptly named “ships of Mercy.” In 1926, the Corps was first put into use flying injured
troops over 150 miles, from Nicaragua to a French Army Hospital in Panama. As air evacuation evolved, it became clear that specially trained personnel were needed to provide care during air transport. Because there were not enough physicians, Brig General David Grant proposed establishing a flight-nurse corps. In February 1943, the first class of flight nurses graduated from Bowman Field in Kentucky. The 4-week course had taught flight physiology, loading procedures and survival skills. During World War II, nearly 100,000 patients were being evacuated per month. A record of 4,704 patients transported in one day was recorded in 1945.

The distinction of providing the first civilian air medical transport goes to the Australian Royal Flying Doctor Service. They took off on their first mission in 1928.

During the 1930s, the US Air Mail service was utilized to evacuate some patients from rural areas to urban hospitals for care. In 1936, the helicopter was first developed in Germany. It is worth remembering that the idea was first recorded by Leonardo da Vinci in the fourteenth century with his drawings of an Ornithopter flying machine. In 1937, Igor Sikorsky successfully flew his VS300. In 1942 the US Army began military helicopter flights. On August 4, 1950, a Bell Model 47 outfitted with two external litters flew the first of over 20,000 medical evacuations in Korea. The Hospital Ship Consolation was even outfitted with a helipad so that patients could be flown directly to awaiting surgeons on board.

With the use of helicopters becoming routine in Korea, people realized that a civilian use of helicopters would be beneficial as well. In the summer of 1951, when a steeplejack fell from scaffolding to the roof of St. John’s Cathedral in New York City, the New York City Police Aviation Unit flew the patient from that accident to a nearby park, where an awaiting ambulance rushed the patient to a nearby hospital. Although this rescue was highly publicized, it took another war to show the true usefulness of the helicopter.

During the Vietnam War, nearly 1 million injured patients were flown, many directly from the battlefield to higher levels of care, and many in just over one hour from the time of injury. The helicopter's role in expediting care was now very clear.

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**CIVILIAN ADAPTATION**

In 1969, as part of an experiment by the Department of Transportation, military helicopters were made available to civilian agencies to transport patients. Military Assistance to Safety and Traffic (MAST) was first offered from Fort Sam Houston in San Antonio, Texas, and later at many other military bases throughout the US. In its first 10 years, MAST assisted with flying more than 16,000 patients.

In 1969, the first hospital-sponsored air medical service was initiated. It was a fixed-wing program based in Phoenix, AZ – Samaritan Air Evac. On March 19, 1970, the Maryland State Police Aviation Command became the first civilian agency to transport a critically injured trauma patient by helicopter. The first hospital-based air medical helicopter program was established in 1972, at St. Anthony's Hospital in Denver, Colorado.

In the United States, the initial growth in this new industry was slow, but the late 1970s saw a steady increase. By the end of 1980, there were 32 programs, flying 39 dedicated medical helicopters. By 1985, the industry surpassed 100 programs and helicopters, and by the end of 1986, there were over 150 aircraft. Over the next 10 years, this figure nearly doubled, with just under 300 helicopters being flown by 202 programs. Now, after more than three decades of rotor-wing flight, the United States has amassed more medical helicopters than many experts might have ever considered possible. By the end of 2005, there were nearly 600 dedicated medical helicopters being operated by 270 services. In addition, there were more than 125 dual-purpose public use and military helicopters that also flew civilian medical missions.

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**EFFICACY**

The question is often asked if the service provided by air medical services is worth the high cost. Only a few studies have been performed that seek to answer this question. In 1983, a University of California study showed a 52% reduction in predicted mortality among trauma patients transported by air versus ground services. The same study showed that the average time from injury to arrival at the trauma center was 58 minutes by air versus 35 minutes by ground. This would indicate that it was the care provided by the air medical service rather than the speed of transport that improved outcome. A study done at The Mayo Clinic in Rochester, Minnesota, in 2001 looked at the outcome of cardiac patients transported by helicopter versus ground ambulance. The results showed not only faster transport times and shorter times to intervention, but also that air transported patients spent on average 2 days less in hospital than those transported by ground. There have been a few studies that question the usefulness of air medical transport and certainly many who speak out against the cost and efficiency of air medical transport. Overall, there has been a lack of outcome studies in this.
industry, a problem that is currently being addressed by the leaders of various organizations in the Air Medical industry.4,7,8,9

AIR MEDICAL ASSOCIATIONS

As this industry grew in the number of services provided and the number of individuals involved, several organizations developed to meet the needs of the many professionals involved in the industry. While a more detailed overview of the following associations, as well as other organizations involved in air and ground medical transport can be found in Chapter 11, this serves as an introduction to several key organizations.

The Association of Air Medical Services (AAMS) is the group that serves as the trade organization representing the industry. The association was founded in December 1980, with approximately 50 people as the American Society of Hospital Based Emergency Air Medical Services or "ASHBEAMS." Their first conference was held in San Diego, California, in 1981, with 100 attendees. The 2005 Air Medical Transport Conference in Austin, Texas, had well over 2500 attendees and 140 educational sessions.

The Air and Surface Transport Nurse Association (ASTNA) was founded in 1980 as the National Flight Nurses Association (NFNA), and currently has approximately 1600 members. This group currently hosts the CONCERN Network for accident and incident reporting.

The Air Medical Physicians Association (AMPA) was founded in 1992 with Frank Thomas, MD, as the first president of the organization. The mission was and still is to enhance the role of physicians involved in air medical and critical care transport. The organization has over 400 members from many different countries.

National Association of Air-Medical Communication Specialists (NAACS) was founded in 1989 with the mission of representing air medical communication specialists on a national level through education, standardization and recognition.

The National EMS Pilots Association (NEMSPA) is dedicated to serving pilots involved in emergency medical service and improving the air medical industry in general.

The International Association of Flight Paramedics was founded in 1986 as the National Flight Paramedic Association. It is the largest independent paramedic association in the United States. The group's focus is to advocate for safety, credibility and performance in the air medical and critical care transport environment.

In addition to these and other organizations entirely focused on air medical and critical care transport, several physician groups have added sections that focus on these areas of transport and care. The American College of Emergency Physicians and the American Academy of Pediatrics are two of the most actively involved groups.

CAAMS, or the Commission on Accreditation of Air Medical Services, later changed their name to CAMTS, or the Commission on Accreditation of Medical Transport Systems. CAMTS is a non-profit consortium of 16 member professional organizations whose goal is to offer a voluntary evaluation of compliance with accreditation standards that demonstrates the ability to deliver patient care of the highest quality in a safe transport environment.10,11

Unfortunately, there are still some "air ambulance" services that have nothing—or very little—in common with those programs that are CAMTS accredited or meet the CAMTS standards. Some aircraft used for medical transport may have a primary mission other than patient transport. They may be quickly configured with minimal equipment and moonlighting medical crewmembers when a flight request is made. Other programs may have dedicated aircraft, but may have limited, if any, medical control, practice standards, education, quality assurance, physician involvement or safety program. This may adversely affect the quality of care and the safety of patient and crew.12

To date, approximately 100 services have been accredited by CAMTS and that number will undoubtedly continue to increase as this industry sets its goals higher and strives towards excellence and continued improvement in safety for its patients and crews.

SUMMARY

Civilian air medical transport began following the early experience and success achieved by the military. During times of war, the numbers and extent of combat injuries demanded rapid transport to medical facilities. In the 1970s, a similar need was becoming apparent within the United States to transport critically ill or injured civilians rapidly over long distances or from remote areas. Now, more than 35 years later, there are more than 700 helicopters and countless airplanes in the U.S. performing life-saving missions. As a "community," air medical transport professionals and associations must focus their efforts on quality patient care, appropriate utilization and a safe transport environment.
REFERENCES

1. Thomas SH. Aeromedical Transport. eMedicine June 25, 2004
11. American College of Surgeons Committee on Trauma. 1991

SUGGESTED READING

INTRODUCTION

Ground EMS systems, like their air medical cousins, grew from the needs of the military. Jean-Dominique Larrey, Napoleon's Surgeon General, developed the ambulance volante to transport wounded soldiers directly from the battlefield, rather than waiting for the fighting to end. During the American Civil War, Joshua Letterman, Joseph Barnes and their colleagues in the United States Army trained corpsmen to render aid on the battlefield, thereby creating the forerunners of today's EMT. Building on the military experience, Cincinnati, New York, Paris, and London established ambulance services. Many of these services were staffed by house officers from the municipal hospital. After World War I some communities established ambulance services, which were staffed by volunteers.

With the demand for physicians in WWII, the need for ambulance care was largely met by the volunteer ambulance services, and by funeral homes. When the war ended, the structure of postgraduate medical education radically changed. House officers no longer were interested or available to staff ambulances, and hospitals were no longer interested in providing this service. Through the 1950s and into the 1960s, volunteer ambulances, fire companies, and funeral homes provided emergency medical transportation.

BASICS OF EMS SERVICES

BACKGROUND

In 1966, the National Academy of Sciences – National Research Council issued a report, "Accidental Death and Disability: The Neglected Disease of Modern Society," which described the failures of the US emergency care system. This provided a strong impetus for the development of the present US EMS system. Other advances, such as the development of CPR and defibrillators added steam to this movement.

Beginning in the early 1960s in Prague and Moscow, and later in Belfast, ambulances began the conversion from a means of transportation to a site of treatment. These services used physicians to bring advanced medical care to the patient's side. In the U.S., the structure of medical care discouraged the use of physicians, but some areas developed highly sophisticated systems using paramedical personnel.

By the early 1970s several organizations, including the American College of Surgeons and the American Academy of Orthopedic Surgeons, began pressing for funding from the US government. Adding to this pressure was the popularity of the television show "Emergency!" which depicted a pair of Los Angeles County Paramedics. In 1973, the US Congress passed the Emergency Medical Services System Act, providing funding for the development of EMS systems in the United States.

Today, EMS still shares many of the attributes of these early systems. Many EMS systems are based in the fire service, or are private services descended from the funeral home-based services. Much of the U.S. is served by volunteer ambulance companies, although increasingly these services are staffed by paid personnel, especially during the business day when volunteers are in short supply. In many other countries, physicians provide care in the prehospital setting, assisted by paramedics or nurses.

EMERGENCY MEDICAL TECHNICIANS

Originally, EMS providers were designated EMT-A for "Emergency Medical Technician—Ambulance." This course was approximately 80 hours in length and trained the personnel to provide basic first aid care, CPR, fracture and spinal immobilization, oxygen administration and control of bleeding wounds comprised the majority of the curriculum. Paramedic (EMT-P) courses, developed much later, ranged from 1000 to 2000 hours or more of instruction. These courses built on the EMT-A course and trained the providers in endotracheal intubation, IV access, rhythm recognition, defibrillation, and drug administration. Many states developed intermediate level provider courses, incorporating various pieces from the full paramedic curriculum.

The development of automatic defibrillators in the late 1980s and early 1990s spurred the development of EMT-D (for Defibrillator) programs. These programs provided the EMT-A with an additional course of in-
struction in how to apply and use automatic defibrillators.

During the late 1980s NHTSA, the National Highway Traffic Safety Administration, began the process of revamping the entire EMT curriculum. The resulting curricula are the EMT-B (for Basic), EMT-I (for Intermediate), and EMT-P (for Paramedic). The biggest change at that time was in the EMT-B program, which added training in automated defibrillation (from the EMT-D), endotracheal intubation (from the EMT-P) and certain drug administration, primarily the epinephrine autoinjector, from the EMT-I.

While these curricula were developed by the U.S. Federal Government, not all jurisdictions have adopted them in their entirety. Many areas have been slow to adopt intubation as an EMT-Basic skill. Some states have retained several intermediate levels. Within each state, local jurisdictions, and even individual programs, may have widely differing levels of care. Air medical program medical directors should become familiar with the capabilities of the agencies in the area that their air medical program serves.

OTHER PROVIDERS

Many areas have first responder programs. This is essentially a first aid program designed primarily for law enforcement and fire personnel who may get to a victim before the EMTs. In some areas, first responders have been trained to use automatic defibrillators.

For many years, dispatching involved simply finding out where the victim was and sending an ambulance from the nearest station. In recent years, the development of Emergency Medical Dispatcher (EMD) programs has changed this function dramatically. These personnel are not only trained to take the call and dispatch the ambulance, but are also able to acquire medical information and assist the caller in aiding the victim until help arrives.

In some areas, police department special operations teams (commonly known as SWAT teams, for Special Weapons and Tactics) have EMTs attached to them. These EMTs have commonly undergone a week-long course in the special needs of medical care in a hostile environment. They provide a bridge between the law enforcement and EMS communities.

Wilderness EMT programs train EMTs in the special skills that may be needed to care for patients under the conditions often found in backcountry areas. These EMTs provide medical functions for search and rescue teams as well as for expeditions. They often have specialized skills needed to care for and extricate patients from difficult and dangerous locations.

TYPICAL EMS SYSTEMS

While there is no "standard" EMS system, there are several common models. The classic model is a service which is based at a station, whether with a fire company or in a separate station or service. These programs often serve suburban and rural communities, and may be based on the volunteer service model. They may also be found in many larger cities, either as part of the fire department or as a "third service."

Many urban areas have what is described as a "high performance" system. These systems do not use fixed bases, but have the ambulances move about between "posts" – usually geographic regions within the city. Typically these systems use computer models that predict where the next ambulance call is likely to occur, and then move the ambulances based on this prediction.

Because of the various levels of training available for EMTs, not all systems operate at the same level. In some areas, the providers are all of a single level, be that Basic, Intermediate, or Paramedic. Some urban systems use a tiered model, in which there are Basic and Paramedic staffed units. Depending on the nature of the call, it may be assigned to either a Basic or a Paramedic ambulance. Some systems use a hybrid system in which the ambulances are all staffed by EMT-Basic providers, but Paramedic care is provided when needed by a paramedic who responds separately in a "fly car." Each of these models has advantages and disadvantages. Again, air medical providers and their medical directors should become familiar with the types of services in their area and with the types of care that they are permitted to provide.

EMS INITIATIVES

Emergency Medical Services for Children (EMSC) is a federal program, begun in 1984, which targets the need for improving the care of children in the EMS system. Children make up a small but important portion of the EMS patient population. Their needs are frequently overlooked as EMS educators and systems focus on the higher volume problems of adults. EMSC, administered through the Maternal and Child Health Bureau and the National Highway Traffic Safety Administration, provides funds and guidance to improve pediatric education and care among EMS providers.

The EMS Agenda for the Future was published in 1996 by the National Highway Traffic Safety Administration, the Health Resources and Services Administration, and the Maternal and Child Health Bureau. This document was the result of input by over 500 groups with an interest in EMS. It identified the importance of
EMI in the future of healthcare in the U.S. The Agenda identified fourteen areas that need to be addressed if EMS is to continue to serve the public. These areas are:

1. Integration of Health Services
2. Research
3. Legislation and Regulation
4. System Finance
5. Human Resources
6. Medical Direction
7. Education
8. Public Education
9. Prevention
10. Public Access
11. Communications
12. Clinical Care
13. Information Systems
14. Evaluation

For each of these areas a panel looked at what the current state was and where it thought the area should go. The panel looked at each of these both from the standpoint of patient types and from the view of various levels of care. This resulted in a three-dimensional matrix, which can be used to focus the issues into manageable pieces. Following the publication of the Agenda, an Implementation Guide was also published; more recently, an EMS Research Agenda for the Future has been created.

INTEGRATION OF AIR MEDICAL SERVICES WITH LOCAL EMS SYSTEMS

Air medical services should seek to develop and maintain good professional relationships with all emergency service agencies within their service area: law enforcement and fire, as well as EMS. Depending on the EMS System, first responders, EMTs or paramedics are empowered with the ability to request a helicopter for scene response. Given the intensity of resources used in a out-of-hospital response, it is essential that the air medical program has provided the field police officer, deputy, firefighter, EMT or medic with appropriate triage criteria and the education required to locate, secure and mark landing zones. Ground providers must also know how to assist in preparation of the patient for air transport and how safely to approach the aircraft and assist the flight crew with patient loading.

The air medical program must take the initiative in developing triage criteria and offering educational programs for local EMS squads. The nature of this training will vary with geographic and system differences.

One effective technique is for a flight team member to give a didactic presentation at an EMS training center, culminating in a landing demonstration by the aircraft. This allows for practice in setting up the landing zone, and offers EMS personnel a close-up, relaxed inspection of the aircraft and an opportunity for dialogue with the pilot and crew. This obviously cannot be done during the chaos of an actual scene response. Secondly, safety training may also be offered periodically at the flight program’s base of operations. A jacket patch, helmet sticker, or other appropriate recognition can be given to those who complete these courses. Use of the labels can assist the flight crew in identifying individuals at the scene who might be of the most assistance. Thirdly, in a similar fashion, a road show can be devised to take safety training to the ambulance garages and municipalities in the rotor-wing service area. In areas where there are many volunteer basic life support services, it is very difficult to have volunteers attend central meetings; the demands of full-time jobs, child-care issues, and the ever-increasing burden of the required training make such meetings difficult to arrange and attend. This road show can incorporate scene safety, “patient packaging,” and basic patient care items. This is a good opportunity to discuss the reasons why a helicopter should be called for scenes or for intercepts in the event that the patient deteriorates while the ambulance crew is transporting the patient. It is often appropriate, as well, to discuss the criteria for a BLS ambulance crew to request an ALS ground intercept for a patient rather than an air intercept. In some systems, law enforcement and fire personnel will provide first response and activate the helicopter before EMS arrives. Many times, law enforcement and fire officials secure the landing zone, regardless of whether they provide first responder patient care. The regional rotor-wing program must account for these differences in landing zone security and provide appropriate training to assure scene safety.

AUTOLAUNCH

A further refinement of rotor-wing response to scenes is “autolaunch,” which may have other names, such as pre-alert or aerial standby. This occurs when the aircraft is launched by dispatch on the basis of bystander or citizen report, before official members of emergency response arrive. This modality requires comprehensive medical oversight and close cooperation among the flight service, ground EMS providers, fire, law enforcement and dispatch. This protocol requires a consensus among the agencies involved, that for specific patients and situations, rapid critical transport from the scene is appropriate. Criteria must be established to determine
when autolaunch is initiated by dispatch. These calls must be debriefed and reviewed for appropriateness and cost-effectiveness (wear and tear on the engines and fuel usage versus transport time and patient care) as part of the quality management process. In the Mayo Clinic experience, for instance, 22% of autolaunches resulted in patient transport, and subsequent financial analysis deemed these autolaunches to be cost-effective. Dispatch and communication centers are the glue that holds the entire system together and allows for better integration of ground and air services and special responses such as autolaunch.

GROUND INFRASTRUCTURE TRANSPORT

Many air services have begun doing ground interfacility transports in addition to their air transports. The patients transported by these ground services are usually too ill for ground ALS services to move, yet they do not require the speed and cost of rotor-wing transport. Critical care ground services are also utilized to transport significantly ill patients in the event that inclement weather prohibits air transport. Reimbursement considerations are paramount when deciding that this kind of transport is needed as another tool in the service’s EMS toolbox. This offers another transport modality so that the right patient can be transported by the right crew in the right vehicle. These units may be staffed by the flight team members in rotation or by separate, ground only staff. Ground critical care units may have many medical staff configurations, as do rotor-wing units: nurse-nurse, nurse-medic, nurse-physician. The common factor that differentiates these air and ground units from typical ALS ground units is the presence of two highly trained critical attendants in the back with the patient, with a third crewmember (usually a basic EMT or perhaps a medic) driving the ambulance. The institution of these critical care ground units requires strong, comprehensive medical oversight and clearly defined guidelines in the dispatch center to ensure utilization of the appropriate mode of transport.

DISASTERS AND HOMELAND SECURITY

Helicopter EMS (HEMS) needs to be integrated into the regional and/or state disaster plan because it brings another dimension to disaster response. In addition to bringing team members with critical care skills to the patients on scene for improved care, the aircraft brings a higher level of triage experience with that crew. The helicopter may also be used for surveillance of the scene by the incident commander, in order to enable better allocation of resources. If part of the mission of the helicopter service, search and rescue can also be done at the disaster scene. Integration of HEMS with ground emergency services brings stronger resources to the scene of a terrorist attack or other disaster, further enhancing Homeland Security by limiting the spread of the event and keeping matters at a manageable level.

QUALITY ASSURANCE AND UTILIZATION REVIEW

The air medical services’ quality improvement program should include review of all scene responses for appropriateness, as well as an assessment of the quality of treatment provided on-scene, both prior to their arrival and during transport. The cultivation of close working relationships with local EMS providers based upon the shared goal of enhancing patient care allows for quality improvement information and recommendations to flow in both directions in a non-threatening manner. Methods to accomplish this include inviting local EMS personnel to participate in quality improvement reviews and to send follow-up letters to referring EMS units. Information sharing has become more difficult with federal HIPAA regulations. As a result, creative ways of staying within HIPAA boundaries, while still including out-of-hospital providers in the quality process, must be sought. The air medical service should also actively participate in any regional or state EMS organization. By establishing regular channels of communication and feedback, the occasional “problem incident” is easily addressed and often prevented. The importance of strong local, regional and state medical direction cannot be overemphasized.

SUMMARY

Good patient care demands that there be close cooperation between public safety services and air medical services. Because of the wide geographic areas they often cover, air medical services should be well versed in the capabilities of all the public safety services in the region. Education of all providers, including police and fire first responders, must be a priority for all air medical services.

SUGGESTED READING

da/emsman.html
INTRODUCTION

Modern air medical evacuation dates to World War II, when the United States successfully transported more than 1.3 million patients by fixed-wing aircraft over three years with an in-flight mortality rate of less than one in 30,000. Helicopters first found use in the Korean conflict and by the Vietnam War had become the mainstay of rapid transport to definitive surgical care.

The successful use of helicopter transport in military trauma was eventually extrapolated to the civilian world. The first civilian helicopter program was established by St. Anthony Hospital in Denver, Colorado, in 1972. Since then, helicopter and fixed-wing transport systems have proliferated. In recent years the air medical industry has experienced a period of significant helicopter expansion. At a presentation during the 2005 Air Medical Transport Conference, it was reported that there were over 600 dedicated medical helicopters in the United States. In addition, there were more than 100 dual-purpose helicopters performing patient transports.

According to the Atlas and Database of Air Medical Services (ADAMS), there were 272 helicopter services, operating 753 helicopters from 614 bases. It was estimated that more than 300,000 patients are currently transported by helicopter annually in the U.S. This suggests a total annual charge for helicopter air medical transport in excess of $1.5 billion. In addition, there are hundreds of dedicated and non-dedicated airplanes that conduct patient transport. Flightweb’s Air Medical Transport Registry alone identifies nearly 200 fixed-wing programs.

As physicians, we approach the transport of a critically ill or injured patient from a variety of perspectives. First of all, we have an obligation to assure that the patient is taken to the most appropriate facility using the right mode of transport. We are also responsible for the safety of the patient and crew and therefore must determine if the risk of transport outweighs the benefits of transferring the patient using any transport mode. Finally, we are also fiscal stewards of the health care system and must not utilize costly resources where other less expensive alternatives are as effective.

The purpose of the current chapter is to review the appropriate indications for the use of air medical transport and to discuss retrospective utilization review criteria for scene and interfacility air medical transport of the critically ill or injured patient.

GENERAL CONSIDERATIONS

In the most general sense, air medical transport is indicated when the benefits provided by the personnel and equipment available during helicopter and fixed-wing transport are greater than the risks of the transport. Several factors must be considered in the transport decision, including the pathophysiology of the patient’s illness; the training and experience level of the transport team; the urgency of definitive care; and the location of the aircraft, the transport team, and the referring and receiving facilities (Table 3-1). Time is obviously an important consideration, with the distance to be covered, the geography involved and local traffic conditions being important factors. Air transport is most beneficial over rough terrain, under heavy traffic conditions and over moderate to long distances. In addition, local and regional health care resources also play a significant role in the decision to use air transport.

Helicopter transport is most effective in travel distances between 15 to 100 miles of definitive care, whereas fixed-wing transport should be considered for transports greater than 100 miles. Under these circumstances, fixed-wing transports are typically faster and more economical than helicopter transport. It must be remembered that helicopter transport often provides direct site to site transport whereas fixed-wing transports require two additional transfers from the referring hospital to the airstrip and from the airstrip to the receiving hospital, in most cases.

In weighing the benefits of air medical transport, four factors must be considered (referred to as the “4 S’s of air transport”): speed, smoothness, special skills (of crew) and access. The most important of these factors is speed. Thus, any patient with an illness or injury that is considered time-dependent is a candidate for air medical transport. On the other hand, patients who require critical care services during transport who do not have a time-dependent condition may be more appropriately transported by ground critical care services if these are
available. We will discuss some of these time-critical considerations later in this chapter, but clearly patients with traumatic injury or acute coronary events are considered obvious candidates for air medical transport.

The smoothness of flight may also be a consideration, particularly for the patient who is transported great distances over rough terrain. Patients with spinal injury or severely hypothermic patients may benefit from air transport since rough ground transport conditions may worsen the patient’s existing medical illness.

The special skills of the medical crew may also be an important consideration in selecting air medical transport. Critical care personnel may be necessary based on the underlying medical condition of the patient. Medical crew proficiency in airway management, critical care medications, and special skills such as ultrasonography may directly benefit the patient. The availability of specialized transport teams including pediatric and neonatal providers, perinatal nurses, circulation technologists, physician specialists and respiratory therapists delivers tertiary services to the patient before arrival at the receiving facility. Air medical transport may be logistically appropriate when local providers are capable of delivering Basic Life Support only, or when the transport of a critical patient might leave a community without any emergency care resources.

Finally, there are rare occasions where air transport is the only method to access a patient for transport. In the urban environment, this may occur when traffic conditions preclude either response or egress from the location of a critically ill or injured patient. Similarly, certain rugged terrain or isolated island environments may not be conducive to ground access, making air transport the only practical option. Other patients in remote rural environments may be best transported using fixed-wing resources.

There are also conditions in which air medical transport is not indicated. Air transport should not be used in the patient who has a stable illness or injury and who is not felt to be at high risk for life-threatening problems during transfer. Such patients should be transported by ground ambulance, which offers a more cost-effective method of transfer and preserves limited air medical resources.

Weather is the other limiting consideration in determining the ability to transfer a patient using air transport. Each helicopter or fixed-wing program is bound by specific weather minimums that must be met before an aircraft can safely fly. It is the duty of the pilot to assess the prevailing weather conditions prior to flight. This decision must be completely objective and made in the absence of any clinical information, thus removing any emotional factors from the decision-making process.

One final concern should be the safety of the flight crew and patient during transport. Each air medical transport carries an inherent safety risk that must be considered before launching a mission. This issue will be addressed in greater detail later in this handbook. Specific concerns regarding any patient safety issues such as combativeness resulting from a medical or traumatic condition must be addressed prior to transport.

The actual decision to utilize air medical transport can be made based on a few simple questions that can be applied to any patient transport (Figure 3-1). The first consideration is whether the distance and time from definitive care are likely to result in net time-savings for the patient in transport. This requires the specific decision-maker to understand the location of the responding aircraft, the distance to definitive care and the road conditions for travel (traffic congestion, speed limits, construction, etc.). If there is a potential for saving time, air transport may be considered. Diaz et al. analyzed almost 9,000 ground and air 911-dispatched transports. The authors found that air medical transport had a faster arrival to the receiving hospital when simultaneously dispatched with ground for transports more than 10 miles and earlier arrival when dispatched after ground transport when the distance from the scene was more than 45 miles.

The next question to consider is whether the patient does indeed have a time-critical illness. Any patient who has the potential for an emergent intervention or procedure should be a candidate for air transport. Examples of such urgent interventions include surgery, cardiac catheterization, electrophysiologic intervention, hemodialysis, cardiopulmonary bypass, balloon pump insertion, hyperbaric oxygen treatment and newborn delivery, to name a few.

A related consideration is whether, in the judgement of the referring physician, minimizing the patient’s out of hospital time might have an impact on the patient’s clinical outcome. Unstable patients requiring care in an intensive care setting are appropriate for air transport even if an immediate intervention is not planned. Trauma victims with fluctuating intracranial pressures

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### Table 3-1: General Considerations for the Method of Transport

<table>
<thead>
<tr>
<th>Consideration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Optimal scene time or interhospital transport time</td>
</tr>
<tr>
<td>2. Patient medical illness or injury</td>
</tr>
<tr>
<td>3. Distance (and time) of transport, including local geography and traffic conditions</td>
</tr>
<tr>
<td>4. Special skills possessed by the medical crew</td>
</tr>
<tr>
<td>5. Weather conditions</td>
</tr>
<tr>
<td>6. Cost</td>
</tr>
</tbody>
</table>

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Chapter 3: Indications for Air Medical Transport: Practical Applications
Air Medical Physician Association

Figure 3-1: Medical Decision-Making in Air Medical Transport

or septic medical patients are examples of this consideration.

Finally, other factors such as special skills of the medical crew and logistical issues such as access and local resources must be addressed in the transport decision.

A similar decision process used to select air transport may be applied in a retrospective manner to each transport to determine appropriate utilization. In this way, the service medical director can identify trends in over-utilization of air transport, address specific problem areas and thus fulfill our obligation to be the stewards of valuable health care resources.

SPECIFIC MEDICAL CONDITIONS

TRAUMA

Air medical transport has its roots in the care of injured patients during wartime and no clinical condition has been as well studied as the impact of air transport on trauma mortality. Many methods have been used to approach this issue, but the most rigorous studies employ TRISS methodology. In this method, trauma patients are stratified according to their Trauma Score, Injury Severity Score, mechanism of injury and age. The study population is measured against a large trauma cohort called the Major Trauma Outcome Study (MTOS). Using this methodology, one determines if the study population has characteristics that resemble to MTOS cohort (M statistic). A reasonable closeness of fit is suggested by an $M \geq 0.88$. The comparison of the study group mortality against the MTOS cohort is defined by the Z statistic. Finally, the W statistic expresses the number of unexpected lives saved per 100 patients.

Baxt and Moody, using the TRISS methodology, were the first to demonstrate an improvement in trauma mortality in patients transported by specially trained crews in a helicopter from the trauma scene, when compared to ground transport. The same study was repeated evaluating seven independent air medical transport services operating in several regions of the country and staffed with differing crew configurations. In each case, a survival benefit was shown by air transport from the scene, although the magnitude of the benefit varied among the programs. An overall improvement in mortality of 21% was demonstrated by air transport. Since that time, several other studies have used similar methodology to demonstrate that air medical transport improves survival when compared to ground transport. It should be noted that these studies have demonstrated a benefit to air medical transport in suburban and rural settings; the use of direct air response in urban settings has yielded mixed results, particularly with penetrating trauma. Finally, the demonstrated benefit of air transport not only applies to direct scene transports but also interfacility transports of trauma patients. The American College of Surgeons has developed algorithms delineating the need for transport to a Trauma Center for both scene (Figure 3-2) and interhospital (Figure 3-3) requests. Where speed is critical or special crew skills are required, air transport is indicated.

The reason for the improvement in survival seems to be related to both the advanced skills provided by the transporting crew and the speed of transport provided by helicopter. Few studies have been able to clearly address which of these factors appears to be more significant. Cameron et al., for example, showed that there was no significant difference in expected outcomes in trauma patients transported by helicopter where special skills such as intubation were not routinely employed in the treatment of patients with major head trauma. This study identified speed as the most important factor in improving survival. On the other hand, Celli and Cervoni demonstrated a profound decrease in mortality when comparing air to ground transport (20% versus 54%) in patients with severe head injury, primarily due to the higher intubation rate among air-transported
Principles and Direction of Air Medical Transport

Measure vital signs and level of consciousness

Step 1: Physiology
- Glasgow Coma Scale < 14 or
- Systolic Blood Pressure < 90 or
- Respiratory Rate < 10 or > 29 or
- Revised Trauma Score < 11 or
- Pediatric Trauma Score < 9

YES: Take to trauma center; alert trauma team

NO: Assess anatomy of injury

Step 2: Anatomy
- Flail chest:
- Two or more proximal long-bone fractures
- Amputation proximal to wrist and ankle
- All penetrating injuries to head, neck, torso and extremities proximal to elbow and knee
- Limb paralysis
- Pelvic fractures
- Combination trauma with burns

YES: Take to trauma center; alert trauma team

NO: Evaluate for mechanism of injury and evidence of high-energy impact

Step 3: Mechanism of Injury
- Ejection from automobile
- Death in same passenger compartment
- Pedestrian thrown or run over
- High-speed auto crash:
  - Initial speed > 40 mph (64 kph)
  - Major auto deformity > 20 inches (50 cm)
  - Intrusion into passenger compartment > 12 inches (30 cm)
- Extrication time > 20 minutes
- Falls > 20 feet (6 m)
- Roll over
- Auto-pedestrian injury with > 5 mph (8 kph) impact
- Motorcycle crash > 20 mph (32 kph) or with separation of rider and bike

YES: Contact medical control; consider transport to trauma center; alert trauma team

NO

Step 4: Co-Morbid factors
- Age < 5 or > 55 years
- Pregnancy
- Immunosuppressed patients
- Cardiac disease; respiratory disease
- Insulin-dependent diabetes; cirrhosis; morbid obesity; coagulopathy

YES: Contact medical control; consider transport to trauma center; alert trauma team

NO: Reevaluate with medical control

Figure 3-2: Scene Triage Criteria
Air Medical Physician Association

<table>
<thead>
<tr>
<th>Central Nervous System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head injury</td>
</tr>
<tr>
<td>Penetrating injury or depressed skull fracture</td>
</tr>
<tr>
<td>Open injury with or without cerebrospinal fluid leak</td>
</tr>
<tr>
<td>Glasgow Coma Score (GCS) &lt; 14 or GCS deterioration</td>
</tr>
<tr>
<td>Lateralizing signs</td>
</tr>
<tr>
<td>Spinal cord injury</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Chest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wide mediastinum or signs suggesting great vessel injury</td>
</tr>
<tr>
<td>Major chest wall injury or pulmonary contusion</td>
</tr>
<tr>
<td>Cardiac injury</td>
</tr>
<tr>
<td>Patients who may require prolonged ventilation</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pelvis/Abdomen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unstable pelvic ring disruption</td>
</tr>
<tr>
<td>Pelvic ring disruption with shock and evidence of continuing hemorrhage</td>
</tr>
<tr>
<td>Open pelvic injury</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Extremity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Severe open fractures</td>
</tr>
<tr>
<td>Traumatic amputation with potential for replantation</td>
</tr>
<tr>
<td>Complex articular fractures</td>
</tr>
<tr>
<td>Major crush injury</td>
</tr>
<tr>
<td>Ischemia</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Multi-system Injury</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head injury with face, chest, abdominal or pelvic injury</td>
</tr>
<tr>
<td>Injury to more than two body regions</td>
</tr>
<tr>
<td>Major burns or burns with associated injuries</td>
</tr>
<tr>
<td>Multiple, proximal long bone fractures</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Co-Morbid Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age &gt; 55 years</td>
</tr>
<tr>
<td>Children</td>
</tr>
<tr>
<td>Cardiac or respiratory disease</td>
</tr>
<tr>
<td>Insulin-dependent diabetics, morbid obesity</td>
</tr>
<tr>
<td>Pregnancy</td>
</tr>
<tr>
<td>Immunosuppression</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Secondary Deterioration (Late Sequelae)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical ventilation required</td>
</tr>
<tr>
<td>Sepsis</td>
</tr>
<tr>
<td>Single or multiple organ system failure (deterioration in central nervous, cardiac, pulmonary, hepatic, renal, or coagulation systems)</td>
</tr>
<tr>
<td>Major tissue necrosis</td>
</tr>
</tbody>
</table>

Figure 3-3: Interhospital Triage Criteria (Adopted with permission, ACS Committee on Trauma: Resources for Optimal Care of the Injured Patient, 1997.)

Air transport is unlikely to provide benefit to patients with only minor injuries (ISS < 16) and equally unlikely to provide benefit to the most severely injured patients who are unlikely to survive their critical injuries. This latter group may be more difficult to define at the time of presentation.

Thomas et al. used regression analysis to review the outcomes of 16,699 patients transported to Level I adult and pediatric trauma centers. Although the crude mortality for air transport was 3.4 times that of ground transport, there was a significant reduction in mortality among those transported by air (odds ratio 0.76; 95%, CI, 0.59-0.98, p = 0031).

Specifically focusing on moderate to severe traumatic brain injury, Davis et al. found the patients transported by air medical transport had an improvement in adjusted mortality (odds ratio 1.09; 95% confidence interval 1.01 to 1.55; p < 0.0001) and good outcome (odds ratio 1.36; 95% confidence interval 1.18 to 1.58; p < 0.0001). Successful out-of-hospital intubation by air medical crews was thought to be a major factor in improved outcomes.

The use of regional or statewide trauma criteria based on the suggested triage guidelines outlined by the ACS (Figure 3-2) should help reduce over-triage of trauma patients. These findings have been confirmed by Cunningham, Jacobs, and Thomas.

It has been shown that patients in trauma arrest have a poor prognosis and specifically that air transport provides no clinical benefit to these patients. Thus, air transport should rarely be considered for trauma patients already in cardiac arrest. These patients should be transported urgently to a local facility or pronounced on scene based on input from on-line medical direction as well as local protocol. One possible exception is the use of air transport for patients with gunshot wounds to the head when potential organ donation is a consideration.

Similarly, data on the use of air transport in the urban environment suggests that helicopters should be used only where a distinct time savings can be identified. Schiller et al. found a mortality of 18% in patients transported by air compared to 13% mortality in a similar group transported by ground in their urban study. In their recent review in an urban setting, Shatney et al. found that the helicopter saved time in only 14.8% of 947 transports and was beneficial in at most 22.8% of cases. Cocanour et al. found that air medical crews provided additional skills in only 4.9% of 122 victims of penetrating trauma and that air transport actually prolonged arrival at hospital time in their metropolitan setting. Further cost versus benefit analysis studies should identify those subsets of urban trauma victims who might potentially benefit from air transport.

patients (80% versus 10%). Biewener et al. have recently challenged this concept by demonstrating similar outcomes in patients transported by air or ground to a Trauma Center. These authors concluded that it was the timeliness and level of service that was the major factor in patient outcome.

Brathwaite et al. examined a statewide trauma registry and found a documented advantage for air transport in three subsets of patients: ISS 16 to 30, ISS 31 to 45 and ISS 46 to 60. This makes intuitive sense since
Principles and Direction of Air Medical Transport

On the other hand, Slater et al.\textsuperscript{34} compared the use of air transport for transport of burn victims. While those patients transported by air medical transport were more severely burned, the authors noted that many patients flown did not have evidence of inhalation injury or high-severity burns. These represent two patient populations that would potentially benefit from air transport. Saffile et al.\textsuperscript{35} specifically studied over-triage in air transport of burn patients. They found that only 60% of patients met published criteria for air medical evacuation. They proposed a role for telemedicine in determining appropriate use of air medical services in this population.

One final point about the use of air medical transport in trauma patients is that helicopters are not only life-saving but they may be cost-effective (Table 3-2). Gearhart et al.\textsuperscript{36} demonstrated that per year of life saved, air transport is far more economical than many interventions that represent common standards of practice in this country. Additionally, to supply a comparably equipped and staffed ground ambulance over long distances may be less cost-effective than air medical transport.\textsuperscript{37}

<table>
<thead>
<tr>
<th>Emergency Intervention</th>
<th>Discounted Cost per Year of Life ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prehospital Defibrillation</td>
<td>820</td>
</tr>
<tr>
<td>Air Medical Transport for trauma</td>
<td>2,454</td>
</tr>
<tr>
<td>Prehospital Paramedic System</td>
<td>8,886</td>
</tr>
<tr>
<td>Neonatal ICU for infants 500-999 gms</td>
<td>18,000</td>
</tr>
<tr>
<td>Median for 310 medical interventions</td>
<td>19,000</td>
</tr>
<tr>
<td>Three-vessel CABG for severe angina</td>
<td>23,000</td>
</tr>
<tr>
<td>t-PA therapy for acute MI</td>
<td>32,678</td>
</tr>
<tr>
<td>Prophylactic AZT after needlestick injury</td>
<td>41,000</td>
</tr>
</tbody>
</table>


CARDIAC DISEASE

In recent years, the treatment of acute coronary syndromes has undergone significant revision. The emphasis of care has turned from post-event interventions to addressing emergent revascularization of the patient with acute coronary syndromes. When early revascularization is achieved, the result is improvement in residual left ventricular function and reduction in mortality. Recent studies have begun to demonstrate the superiority of mechanical revascularization over thrombolytic agents.\textsuperscript{38} Percutaneous intervention (PCI) is most beneficial when undertaken by experienced providers in an active catheterization lab with cardiothoracic surgical support. However, the intervention must be accomplished within 60 minutes from the potential administration of fibrinolytic agents.\textsuperscript{39} Several European studies have demonstrated that long distance transfer of patients for PCI shows benefit over locally administered fibrinolytic agents.\textsuperscript{40,41} This appears not only to be true for patients with acute ST-elevation myocardial infarction, but is also emerging as the therapy of choice in patients with unstable angina.\textsuperscript{42}

Air medical services are an obvious consideration where there is a need for rapid transport of a critically ill patient to specialized centers capable of providing emergency cardiac interventional services. Several studies\textsuperscript{43-46} in the late 1980's were the first to demonstrate that patients with acute myocardial infarction (AMI) could be safely transported via helicopter to tertiary care centers. These authors were able to demonstrate that complication rates were low in this population. Straumann et al.\textsuperscript{47} specifically addressed the issue of safe transport of patients with AMI being transported for primary PTCA. They showed that air transport of such patients could be done safely even in unstable patients, thus extending their "coverage area" for primary angioplasty. Finally, two additional studies demonstrated that patients who required cardiac pacing could be safely transported in the air medical environment.\textsuperscript{48,49}

Others have disputed whether air transport poses an increased risk in patients with acute coronary syndromes. Tyson et al.\textsuperscript{50} suggested that air medical transport may pose a potential risk to patients with AMI and unstable angina as the result of substantially elevated catecholamines during air transport. These findings tended to be supported by Schneider et al.,\textsuperscript{51} who found a significant increase in serious untoward events (new arrhythmia, worsening chest pain, hypotension, bradycardia, cardiac arrest, respiratory arrest or seizure) in cardiac patients transported by air when compared to ground transport. A higher complication rate was not confirmed by Jaynes et al.,\textsuperscript{52} who demonstrated no significant difference in adverse events when directly comparing ground and air transport. Fromm et al.\textsuperscript{53} specifically focused on bleeding complications in patients receiving thrombolytic agents and found no increase in these complications.

Only a few studies have attempted to directly compare the outcomes for air and ground transport of acute cardiac patients. Some of these studies have been limited by small sample size, poorly matched controls and lack of a large database, such as MTOS, in which risk stratification can be easily linked to out-
comes. Stone et al. found an increased total mortality for cardiac patients transported by air and no significant improvement in ICU length of stay, total length of stay and 72 hour mortality. Berns et al. showed an improvement in time of delivery, chest pain upon delivery and total hospital stay for air transported patients but no demonstrable improvement in mortality. More recently, however, Grines et al. showed that high-risk patients with acute myocardial infarction who were air transported for PTCA had a reduced length of stay (6.1 vs 7.5 days), less ischemia (12.7% vs. 31.8%) and fewer complications (8.4% vs. 13.6%) than patients who were transferred to a tertiary center following intravenous thrombolytic agents. These findings were noted despite a difference in symptom onset to intervention difference of nearly two hours.

Clearly, more studies are needed to define the role of air medical transport in acute management of acute coronary syndromes. The parameters under which helicopter transport of patients with an acute myocardial infarction for angioplasty have also been elaborated. Intuitively, it makes sense that the ability to provide rapid transport to a tertiary center with invasive catheterization capabilities will become a central tenet in management of acute cardiac disease, especially as a central role for early mechanical revascularization unfolds.

**CARDIOPULMONARY ARREST**

Air medical transport would be a reasonable option to provide highly trained personnel to patients in cardiac arrest. This would be particularly so in areas where only basic life support personnel are available to provide care.

Lindbeck et al. reviewed the experience of their air medical program in responding directly to the scene in cardiac arrest. Of the 84 patients studied, only 10 (11.9%) survived to hospital admission. Efforts at resuscitation were terminated on scene in 55 cases. Only one patient survived to hospital discharge and this patient had been successfully resuscitated at the scene prior to the arrival of the helicopter. Johnson and Falcone reviewed their ten-year experience with scene responses for medical cardiac arrest. These authors concluded that there was not sufficient success to justify air medical response to the scene and that these transports were not cost-effective.

Werman et al. have studied inter-hospital transport of 170 patients following adult cardiac arrest by helicopter over a 4 year period. Patients with primary cardiac disease had a much greater likelihood of ultimate survival when compared to non-cardiac causes of cardiopulmonary arrest. In fact, 45% of patients with primary cardiac arrest survived to hospital discharge. There was no cost-benefit analysis performed, but the study suggests that inter-hospital transport of cardiac arrest survivors may be justified, particularly in patients with primary cardiac arrest. Further study is needed to define the benefits of transport in patients with non-cardiac causes of arrest, including drowning, medical illness, suffocation, electrocution and smoke inhalation.

Thus, it appears that direct scene response for patients in cardiac arrest is not supported by the medical literature. Patients who have been successfully resuscitated and have been stabilized in a local health care setting appear to benefit by transport to a tertiary care setting, particularly those with primary cardiac disease. Further study is needed in this area to define the role of air medical response to the scene of a successful resuscitation and for inter-hospital transport of patients with non-cardiac causes of arrest. Also, the role of air medical transport in support of areas served by only BLS providers may merit further study.

**NEUROLOGIC**

The treatment of patients with acute cerebrovascular events has also undergone revolutionary changes in the past few years, with the finding that early thrombolysis improves outcomes. Specialized centers have developed that are capable of providing early thrombolysis given intravenously within the first 3 hours of symptom onset or intra-arterially within six hours of onset under the direct supervision of specially trained neurologists and interventional radiologists. The time-dependent nature of this condition makes consideration of air medical transport obvious.

There have been few studies investigating the role and benefit of air transport in this setting. Chaala et al. showed that air medical transport could safely transport patients who had received or were receiving thrombolytic agents for acute stroke. Conroy et al. further demonstrated that helicopter transport had an important role in transporting candidates for acute neurologic intervention. Only 3% of patients were excluded because of time considerations. However, 48% of patient did not receive thrombolytic therapy because of other exclusions. Both Silliman et al. and Thomas et al. have described their experience using air medical transport in interhospital and scene response to stroke victims. Silbergleit et al. determined that it costs about $3700 per quality-adjusted life-year for air medical transport to a tertiary stroke center and concluded that this was a cost-effective intervention. The National Association of EMS Physicians and Air Medical Physician Association have developed position papers supporting the use of air transport in acute cerebrovascular disease.
Clearly, more study in this area is needed, but it appears that air medical transport has a potential role in acute stroke. The costs and benefits of providing air transport services to these patients need further analysis.

**OBSTETRIC**

High-risk obstetrical patients often require care in specialized settings. Additionally, such patients typically require careful monitoring during transport and often have a time-dependent condition. Patients in active labor should experience limited out-of-hospital time. Only a few studies have evaluated the use of air transport in this population. Elliott et al. described their experience in transporting high-risk obstetrical patients using a specialized crew and compared outcomes to a cohort of non-transported patients. The authors noted that there were no maternal deaths among the 100 patients transported and 14 neonatal deaths. These results were comparable to the non-transport group. The study authors supported the potential use of air medical transport in this population.

Low et al. conducted a national survey of air medical programs in 1985 to determine the experience in perinatal transport. The authors reported no incidence of precipitous delivery in flight; seven transports were aborted for rapid progression of labor. The authors concluded that perinatal transport of high-risk pregnancies with delivery in a tertiary care center is cost-effective and that air medical transport plays a significant role in this system.

Recently, Van Hook et al. reported on their one-year experience in the transport of 22 high-risk pregnancies. They had no deliveries or significant complications among this population. The authors were unable to find any significant differences among those patients who delivered after transport and those whose contractions abated. The authors supported a role for air transport in a regional perinatal care system.

These studies support the safety of air medical transport in high-risk obstetrical patients. However, further studies comparing outcomes between air and ground transported patients and a cost-benefit analysis are needed.

**OTHER CONDITIONS**

The use of air transport in other time-dependent medical illnesses has been studied in only a few other settings. Kent et al. described the safety of air transport in patients with abdominal aortic aneurysm. In particular, the transport of patients directly to the operating suite was touted by the authors. There is a paucity of data addressing the role of air transport in the treatment of aortic vascular disease, vascular occlusive disease and other surgical emergencies, despite the widespread use of air transport in these conditions.

Hypothermic patients are occasionally transported by air medical services. A review of 17 patients transported for treatment of hypothermia showed no adverse consequences resulting from helicopter transport.

Air transport has allowed the delivery of specially trained neonatal nurses and appropriate medical equipment from the tertiary care center to the community setting. Pieper et al. described their experience using rotary and fixed-wing transport to provide specialized care to 52 neonates. These authors found a lower mortality rate among air transported patients when compared to ground transported patients. This study supported the delivery of specialized neonatal services to the newborn in improving outcome. Berge et al. described their 14-year experience in transporting critical neonates in central Norway. They were able to provide neonatal specialty services to a wide variety of neonatal problems.

Since the major benefit of air medical transport is the rapid provision of specialized care to the bedside, Werman and Neely described the use of air medical transport as a method of delivery with ground transport being used to transport the stabilized infant and team to the tertiary center.

Interestingly, there have been few studies to evaluate the use of air medical transport in transporting critically-ill pediatric patients. In this setting, the specialized training of air medical crews in this area may provide additional benefit over ground crews that are less comfortable with this population.

Finally, the use of air medical transport in support of disaster efforts and as part of search and rescue operations has only recently been addressed.

**FUTURE DIRECTIONS**

There is a significant body of literature that supports the benefit and cost-effectiveness of using air medical transport in trauma. There is some support for the use of air transport in pediatric trauma. Future studies must help us define more specifically the patients who truly benefit from air transport by eliminating those patients who are either so mildly injured or severely injured that the mode of transport or skills of the crew do not provide significant benefit.

Similarly, there is some support for the use of air transport in acute cardiac and neurologic conditions in providing timely care to these patients. Determining the cost-effectiveness of air transport in these conditions...
and finding methods to define the appropriate populations need further study.

There continues to exist gaps in our understanding of the role of air transport in other conditions in which time-savings and special skills may have an impact on outcome. Obviously, this area is wide open for further study. At this time, we must continue to rely on discussions among the referring and receiving physician along with the air medical service program director to determine the appropriateness of air transport for a variety of medical and surgical conditions.

**UTILIZATION REVIEW**

While it is true that many patients appear to benefit from air medical transport, over-utilization of air transport services continues to have both economic and safety consequences. Consider victims of trauma in which studies have clearly shown a survival advantage using air transport. Moront et al. demonstrated that air medical transport of pediatric patients resulted in 11 lives saved per every 1,000 patient transports. This study also showed, however, that 86% of patients were over-triaged to helicopter transport. Others studies have concluded that there is a high rate of over-trieage for air medical transport, particularly among pediatric patients. Similarly, Hotvedt et al. found that 76% of medical and surgical patients transported gained no benefit from air transport since they received no specialized intervention during or immediately after transport. In trauma patients, reliance on strict local or regional trauma triage criteria based on those developed by the American College of Surgeons (Figure 3-2) will help to minimize over-trieage.

Each air medical program has the responsibility to conduct an analysis of the appropriate utilization of air transport. Transports should be scrutinized to evaluate appropriate indications for use of air medical transport by the local and regional health care providers. It should be noted that some degree of over-utilization of air transport is inevitable; currently, however, there is no universally accepted standard for over-utilization.

The Commission on Accreditation of Medical Transport Systems (CAMTS) has proposed screening criteria that can be used to determine inappropriate use of air medical transport (Table 3-3). All transports should be screened against these criteria. Any transports that fail out must be carefully reviewed by the program medical director. An alternative approach is to review each transport against the broad medical indications provided by the Air Medical Physician Association (see Figure 3-4). Many programs require written verification by the referring physician of the medical necessity of air transport based on the patient’s underlying medical or surgical condition. This documentation can be invaluable in the retrospective review of such transports.

Remedies for problems identified by this approach can include individual counseling, outreach education, medical screening, and policy and protocol revision.

**SUMMARY**

The air medical transport industry has grown significantly in the past several years. With this growth comes pressure to utilize air transport for both scene and inter-hospital responses. Air medical transport can be justified when the speed of the aircraft, the special skills of the crew or the smoothness of flight is thought to benefit the patient. In addition, helicopters and airplanes may be utilized under conditions of limited access. Adverse weather and safety concerns may preclude the use of air medical transport even when clinically indicated. There is strong evidence that air medical transport is both clinically useful and cost effective when used in patients with significant traumatic injuries. A growing body of evidence supports the use of air transport in selected cardiac and acute stroke patients. Many other patients may benefit due to the time critical nature of their illness, the need to minimize out-of-hospital time and the special skills of the crew. The medical direc-
Figure 3-4: Medical Condition List and Appropriate Use of Air Medical Transport (AMPA Board of Directors: Medical condition list and appropriate use of air medical transport. Air Med J 22:1-9, 2003)
port with the outcome of injury in trauma patients transported from the scene. *J Trauma* 43:940-6, 1997.


INTRODUCTION

Heat, cold, noise, low light, confined space, lack of support staff, minimal back up equipment and resources, limited accessibility to the patient, petrochemicals and hazardous wreckage. Sounds like a disaster area. Yet these are only some of the issues that air medical transport crews face daily. Including a physician as a member of the flight team does nothing to reduce the impact of these considerations.

The medical training for emergency physicians equips them for dealing with every conceivable type of illness and injury, but does little to train them how to take that knowledge and work successfully in an aircraft or the scene where the aircraft may land. The core content of emergency medicine mentions very little regarding the practice of medicine in the field or in an aircraft,¹ and it is doubtful that routine residency training provides adequate preparation for physicians practicing as flight physicians. This may be especially true if the flight physician is a resident who has not yet completed emergency medicine training. The same can be said for pediatric and surgical residencies or fellowships, or any training program that provides an opportunity for physicians-in-training to participate in helicopter or fixed-wing air medical transport.

Less than five percent of all medical helicopter programs fly with physicians as part of the assigned crew. While some of these programs fly with attending level physicians, the majority of flight physicians are residents-in-training. With this in mind, most of this chapter will deal with the type of training given to residents for this role. This chapter will discuss existing training programs for resident flight physicians and will suggest a possible model-training program.

RESIDENT ORIENTATION

Guidelines or standards for the clinical and didactic education of air medical crews have been developed by numerous professional organizations, many states and the Commission on Accreditation of Medical Transport Systems (CAMTS). However, in this era of evidence-based medicine, there is little available to educate us as to how to train flight physicians or what may be considered the best training. Guidelines for training have been written by the National Association of Emergency Medical Services Physicians² and the Society of Academic Emergency Medicine.³ These guidelines, although helpful, only suggest content and may fall short in some areas. For example, Krohmer¹ mentions an “aircraft tour and orientation” as well as an “orientation flight” while Norton¹ mentions a “flight (if feasible).”

In general, other members of the helicopter EMS (HEMS) flight crew (nurses, paramedics, respiratory therapists, and so forth) complete a comprehensive clinical and non-clinical curriculum that includes a significant number of orientation flights prior to assuming patient care duties. In contrast, is it possible to adequately prepare a physician, whether a resident or attending, to function competently in an aircraft while caring for a patient under stressful circumstances without any training flights, or with just one?

There are numerous questions regarding this educational process for residents. At what year of training are they adequately prepared to function as a flight physician? What training, specific to this role, should they receive and what should it include? How often should they be evaluated and who should carry out the evaluation? Should they have a formal checklist to go through when they show up for a shift? How much continuing education should they have? With these questions and many others in mind, a research project was undertaken that surveyed those Emergency Medicine residencies in the United States that listed flight physician experience as an elective or required experience on the Society of Academic Emergency Medicine web-based residency catalog.⁴

At the time of survey distribution, twenty programs were identified in which residents served as flight physicians on rotary wing aircraft. All but two of the programs returned the survey (90%). The results of that survey will be discussed along with the ramifications for resident performance.⁵
RESIDENCY FORMAT

AND RESIDENT ROLE

In order to strictly define the role the residents played while on the aircraft, three distinct roles were defined:

1. **Flight physician**: acts as a care provider working with one other crewmember (flight nurse or paramedic (EMT-P)) assessing and treating patient, performing procedures and giving medical direction/control to other crewmembers, present on every flight.

2. **Third crewmember**: acts as a care provider in addition to regular crew, assists regular crew but does not provide medical direction, does not serve as an everyday crewmember.

3. **Observer**: may occasionally assist in patient care, or does not provide patient care and is not an everyday crewmember—rides along with crew for further pre-hospital/EMS experience.

Of the twenty programs contacted, eighteen followed a PGY 1-3 format, two were a PGY1-4 format and one was a PGY 2-4 format. Of the 18 responding programs, sixteen (89%) indicated the resident functioned as a flight physician. Two (11%) indicated the resident served as a third crewmember. In one program (5%) the resident served as a flight physician on medical calls and inter-hospital transports but functioned as an observer for scene/EMS runs, which accounted for 20% of the program’s flights. This may have been influenced by the total number of flights the residents did during their residency, which averaged only five. With a low number of flights, the program may have viewed the residents as having sub-optimal experience to function independently as a flight physician at a scene versus at another emergency department (ED). Of note, the sum of the various roles is greater than 100% due to the fact that residents serve multiple roles in some programs.

It will come as no surprise that the crew configuration when a resident was flying was most frequently nurse and physician. This was the case with 94% of programs. However, not all programs flew nurse/physician crews consistently and 11% of programs flew both nurse/physician and paramedic/physician crews. No program flew paramedic/physician crews exclusively. For one program the crew consisted of resident physician, nurse and respiratory therapist.

SCHEDULING

At what point are residents prepared to serve as flight physicians? The majority of programs started residents at the PGY2 level (61%). One program (6%) indicated residents began flying as a PGY1, three (16%) started at the PGY3 level and three (16%) started as a PGY2 or PGY3. Resident readiness to serve as a flight physician is likely a product of the residency curriculum and the training residents receive to serve as flight physicians.

Residents flew at various times during their residency. Forty-four percent flew during all ED rotations, 33% flew as “moonlighters,” 5% flew only as “moonlighters,” 28% flew during a designated air medical rotation and 28% flew during “some ED rotations.” The sum is greater than 100%, indicating some residencies had their residents fly during a combination of months (i.e., during ED months and during an air medical rotation month). Unfortunately, we were unable to solicit the actual frequency with which residents flew (i.e., weekly, monthly, etc).

Base location of the helicopters also varied among the programs surveyed. Aircraft were based at the hospital for 67% of programs. Four programs (22%) were based remotely from the hospital and 11% of programs had aircraft based both at the hospital and remotely.

MISSION PROFILE

Residents cared for a wide variety of patients while serving as flight physicians. All programs transported adult and pediatric patients, as well as both trauma and medical patients. One program transported primarily children, but did transport the occasional adult. Thirty-three percent transported patients on balloon pumps and 11% transported patients on ECMO. A small number of programs also transported patients on ventricular assist devices.

The type of transports completed by resident flight physicians varied widely across the survey population. The mean percentage of scene flights was 26%; the median was 20% with a range of 0 to 80%. The mean was greater than the median because one program listed the percentage of scene responses as 80%. The mean percentage of inter-hospital transfers was 74% with a median of 80% and a range of 20 to 100%. Once again, the mean was disproportionately affected and was less than the median because one program listed the percentage of inter-hospital transfers as 20%.
MISSION VOLUME, PROFICIENCY AND CHECKLISTS

The number of flights and flight hours completed by individual residents also varied widely across the survey population. The mean number of flights completed during their residency was 78.0, with a range of 5 to 212.5 flights. The number of flight hours ranged from 5 to 500, with a mean of 143 and a median of 100. These numbers were obtained from the flight program medical directors. Some may have been estimates while others may have been tracked by some method.

Transport volume and flight hours, as well as when residents are available for flights (i.e., as part of an air medical transport month versus during all their months in the ED), will have an effect on their proficiency. Although there is no literature addressing this issue, anecdotally, residents that fly more frequently are less likely to lose air medical transport-specific skills compared to those who fly infrequently. Skills such as ventilator operation, radio operation, knowledge of equipment location and safety awareness likely diminish at an, as of yet, undetermined rate. The required interval for refresher training on such issues remains undetermined. One could make the argument that such issues should be covered at the beginning of every flight shift, either as part of the flight briefing or as part of a checklist for the resident to complete.

The use of checklists varied significantly, with 72% of the survey population requiring residents to complete an aircraft or medical equipment checklist. Of that group, 70% required that this be done every shift, 8% required this every three months, 23% required it once every 6 months and 8% required checklists only once a year. Twenty-eight percent of the programs surveyed didn’t require any checklist completion. This begs the question as to how frequent checklist completion should be required and how to assure it is done versus just checked off and handed in. The pilots of the aircraft complete a checklist for every takeoff and landing, according to FAA regulations (Federal Aviation Regulation 121.315). As part of an air medical transport team, shouldn’t the flight physician be held to the same accountability? The rate of error in medicine has recently been reported by the Institute of Medicine.7 Equipment and safety checklists, although admittedly unproven in the setting of air medical transport, are aimed at helping reduce error. Interestingly, most pilots who are involved in accidents believe they are acting in a competent manner, yet the cause of most aircraft accidents is an “accumulation of disregard” for safety.8 The parallels between safety in medicine and aviation are obvious.

Not only does a checklist help assure familiarity with the equipment for a resident, but it will allow cross-checking of the flight nurse’s inventory of equipment, serve as a quality control tool for the medical director and hopefully enhance teamwork if it is completed with the flight nurse or other crewmember.9 Not knowing where to find rescue airway equipment for a critical patient with a difficult airway can have catastrophic results. Having the resident review equipment locations at the beginning of every shift will help ensure that they can find the needed equipment rapidly. Specific checklists covering such things as scene landings, ventilator set up and hard landings aid the resident in remembering issues that are crucial to safe and proficient performance.

Checklists, if employed, need to be completed item-by-item and not done from memory.9 Such checklists should include all medical equipment (stretcher, ventilator, airway bag, etc.) drugs, and safety procedures. As part of a safety checklist, during their shift briefing the crew should discuss the procedure for a scene response/landing and routine emergency procedures for a hard landing.

ORIENTATION AND TRAINING

All but one of the programs (94%) had a training course in place that was required before serving as a flight physician. They averaged 5 hours in length with a range of 2 to 24 hours. Only one third of programs test the resident at course completion to demonstrate competency. All courses contained didactics on the subjects listed in Table 34-1.

- Flight physiology
- Aircraft safety issues
- In-flight aircraft emergencies
- Scene-response safety issues
- Communications (how to use aircraft communication system and give report)
- Crew-crew interaction
- Crew-referring agency/referring physician interaction
- Patient scenarios
- Care of the patient in the air medical environment
- Aircraft medical equipment
- Aircraft oxygen equipment

Table 34-1: Didactic Topics for Flight Physician Course
SCENE FLIGHT ORIENTATION

Despite the significant number of scene responses by many of the programs (44% of programs had a 30% or higher scene response rate), only 22% of programs provided a separate “on the scene” training course to teach the dangers and hazards of scene responses and auto extrication. Fifteen of the seventeen programs indicated they had a formal orientation course to cover scene response safety issues. Only one program had the residents complete a mock scene run in which the resident has to do a history and physical exam and package the patient for transport. These types of scenarios not only convey the needed information, but also put the residents through the physical motions they will need to perform. This may aid in retention compared with traditional didactics. They also offer the benefit of giving the medical director and/or other faculty the opportunity to observe the residents’ performance when they otherwise may not have the opportunity. Potential errors may also be identified and corrected.

The amount of training residents get regarding scene safety is unknown, as is the amount required to make a resident proficient and safe at a scene. Given the atypical nature of medical practice as a flight physician, residents may benefit more from non-traditional teaching methods, such as role-playing and mock patient scenarios.

In programs with a larger number of scene flights, residents may eventually become competent at an accident scene, but this is one area where the residency curriculum is lacking. It would seem that implementation of a training program that provides residents with the necessary tools to function efficiently and safely at their first scene response, rather than expecting them to acquire this knowledge and experience “on the job,” would be beneficial.

ORIENTATION FLIGHTS

Fifteen percent, or three programs, require orienting residents to complete one to three flights, without patients on board the aircraft, prior to assuming flight physician responsibilities. One of these programs required no flights with patients on board, one required 1-3 flights with patients on board and the third required 4-6 flights with patients on board prior to the resident assuming the role of flight physician. The number of patient flights required prior to assuming flight physician responsibilities varied. The majority of programs (44%) required 4 to 6 flights. 22% required more than ten flights. 22% required no flights with patients on board and 11% require 1 to 3 flights. Again, the exact number needed to make a resident proficient are unknown and likely will be program-dependent and may be influenced by the Emergency Medicine Residency Review Committee imposed duty-hour restrictions. Given the markedly different environment of air medical transport, having completed at least a few patient flights as an observer or third crew member can only be beneficial.

With whom the residents fly during their orientation flights is also variable across the responding residences. The resident flew with an attending physician and flight nurse in only three programs during orientation flights and in only one did they fly with an attending physician during all orientation flights. In four programs (29%) the residents fly with a nurse or paramedic; for the remainder of programs orienting residents fly with some combination of upper level residents (eight programs PGY2, nine programs PGY3, and two programs PGY4). Thus the majority of bedside teaching for residents training to be flight physicians comes from non-faculty personnel. This may be appropriate given that most emergency medicine faculty are likely to have much less experience in air medical transport than the flight crews or resident flight physicians. However, residents still require attending supervision and the closest attending supervision for a resident serving as a flight physician is often a radio or phone. The usual emergency department situation of an attending physically present to verify resident decision making and aid in difficult procedures doesn’t exist during flight duty.

SUPERVISION AND EVALUATION

Only two programs made an attempt to have faculty observe residents while serving as flight physicians. One program stated this was done one to three times per resident, while the other observed only some residents. The significant time constraints on faculty, as well as the limited number of faculty available or willing to do this, is a real limitation. It is much easier to observe residents in a busy ED, where they are constantly seeing patients and one faculty can directly observe many residents. Observing residents on flight shifts means faculty can’t be in the ED. They would have to give up a significant amount of time waiting for a flight request to come in and could only observe one resident in a given time period.

With these realistic constraints, it is more important that residents receive some type of formal evaluation and feedback regarding their performance as flight physicians. Within the survey population, only five of eighteen programs (28%) utilized written performance evaluations for resident flight physicians. Input for these evaluations typically came from the program medical director and flight nurses, often including the chief flight
nurse. Three programs completed evaluations on residents monthly, one program completed them every six months, and one completed them after a dedicated flight month.

A continuous quality improvement (CQI) process to help identify diagnosis and management errors by resident flight physicians was in place in 89% of the programs. Errors that were discovered were communicated to the physician in question by all of these programs. Actual details of the extent of the CQI process were not solicited. Ideally, the CQI process would include patient treatment outcomes (i.e., for trauma, cardiac, pediatric, burn patients, etc.) airway management, as well as patient and crew safety issues. Both written evaluations and CQI feedback can serve as a substitute for bedside attending supervision. How effective or ineffective the CQI process is in changing resident behavior in this environment is unclear.

**PATIENT AND AVIATION SAFETY**

Patient safety and aviation safety issues may be best reinforced when presented and discussed in conferences or review sessions. The final area addressed by the survey was residency conferences regarding air medical transport cases and patient care. Eighty-nine percent of programs indicated these took place within their residency programs. However, the frequency of these ranged from monthly (39%) to every 3 years (40% monthly, 20% quarterly).

Residents and other crewmembers should be encouraged and able to report safety issues—both personnel and patient, especially "near misses"—without fear of reprimand. Studies done in the hospital environment are particularly applicable to resident and patient safety in the air medical transport environment. Welsh et al. found that utilizing a daily patient log along with daily reminders to report adverse events increased the number of events reported by residents eight times while doubling the number of events reported in the hospital. This could easily parallel the daily briefings of a flight program. O’Neill et al. compared the capture rate of chart review versus confidential resident reporting to identify adverse events on an internal medicine service. Although both turned up a similar number, those reported by residents were more amenable to prevention. These issues need to be integrated into regular safety program reviews. The development of an anonymous formal database for medical management issues and crew safety issues shared amongst programs where residents train could be helpful. If this is not done, simple routine communication between programs via phone or a list serve may suffice.

Safe behaviors for residents need targeting and should be addressed as part of all training programs. The author knows of two specific examples that have occurred on the helipad that highlight this point. An intern, approaching the aircraft for an orientation flight, walked around the moving tail rotor to board the aircraft. While interns were ardently cautioned against this during their initial orientation, this has happened on multiple occasions. In another more disturbing incident, another intern headed to the aircraft for an orientation flight at night. The aircraft was at full power and the pilot, unaware that the intern was going to accompany the crew on that flight, made one last visual scan of the area prior to take off as he was getting ready to pull the collective. At that time, the pilot saw the intern standing on the skid trying to open the rear door. These events represent systems issues that need to be addressed. It is safe to say that, with regards to patient and medical crew safety, none of us truly know the denominator of unsafe events that may occur within our flight programs.

**SUMMARY**

A minority of flight programs utilize physicians as crewmembers aboard their HEMS aircraft—some with attending level physicians, but more are residents. Unfortunately, for medical directors who are responsible for overseeing resident flight physicians, many questions remain to be answered: How do we best train the residents for this role? What is the ideal length and content of a training program for residents doing air medical transport? How should residents be evaluated, both for proficiency and medical decision making in a non-traditional environment? How can this experience be maximized for the benefit of those participating?

What constitutes the best training and continuous education process for resident flight physicians? There is limited data suggesting what the best practices might be to prepare the residents for this unique role. However, effective training for residents in the non-traditional environment of air medical transport is necessary.

From information obtained from the aforementioned survey, as well as experience serving as a flight physician (both a resident and attending), an ideal flight training program would contain the elements identified in Table 34-2.
• Minimum of 5 orientation flights with patients on board. These should be done in reasonable temporal proximity to the time the resident starts her or his duties (shouldn’t all be done in August when the resident begins flight physician duties in the following July).
• Extensive flight physician course with emphasis on air medical transport environment/equipment, teamwork, and safety. Specifically address a difficult airway algorithm and what adjuncts are available to them while on the aircraft versus in the ED. Scene safety should be emphasized. Strong consideration should be given to patient simulation scenarios as well as a mock scene run.
• Proficiency testing throughout residency, especially after flight physician course and prior to duties as a flight physician.
• Daily checklist covering aircraft, medical equipment and safety procedures.
• Daily brief with other crew (pilot and nurse) to include safety procedures.
• Regular review of each resident’s performance with written feedback.
• Checklists for residents for specific situations (scene landings, ventilator set up, routine safety issues, hard landings).
• Extensive quality improvement process with regular feedback to residents on such things as airway management, scene efficiency, following of safety procedures and communication skills.
• Systematic process to capture and correct personal safety issues of residents and flight crew. This should include interaction with data from multiple programs to help improve safety across the industry.
• A thoroughly indexed manual with all information from the training course and sessions for reference.

Table 34-2: Recommended Flight Physician Training Program

REFERENCES

INTRODUCTION

Air medical directors must be familiar with the many limitations and conditions that the transport environment may place upon the patient and medical crew. These unique challenges are true for both helicopter and fixed-wing transport and can significantly impact patient care and medical crew safety. Because of this, altitude and flight physiology must be an important part of an air medical director's knowledge base and must be incorporated in the training of air medical crewmembers.

There are two subjects to review with respect to flight physiology. The first, altitude-related complications, addresses the physical gas laws and predicts how the human body will respond to the changes in atmospheric pressure, temperature, and volume. The second category deals with the stresses of flight.

It is important to consider, however, that we are no longer dealing only with altitude or flight physiology. While altitude physiology and the stresses of flight may have the greatest impact during fixed-wing transport, helicopter transport is not immune from these stresses—especially for helicopter programs that may fly at significant elevations. An understanding and knowledge of these same stresses are also advantageous for transport personnel who use ground ambulances. More appropriately, the topic might be referred to as “transport physiology and the stresses of transport.”

An in-depth understanding of transport physiology is essential to allow the medical team to provide optimal patient care in the transport environment, especially when transporting a patient whose condition is already compromised.

HISTORY

The effects of altitude on the human body have been noted for centuries. The first manned hydrogen balloon ascent took place in 1783, achieving an altitude of 9,000 feet (2750 meters). During this two-hour flight, the solo pilot began to experience the physiologic effects of his new environment. These effects included a drop in temperature during ascent and a feeling of sharp pressure in one ear as he descended. Ten years later, a physician pilot and his passenger documented the first objective physiological changes at altitude. On the ground, the pilot's pulse was taken and found to be 84 beats per minute. At altitude, the pulse was now measured to be 92 beats per minute.

In 1804, the dangers of high altitude travel were first demonstrated. At an altitude of over 20,000 feet (6,000 meters), the crew experienced vomiting, frostbite of their hands and feet, and loss of consciousness. The flame in their lantern went out. Nearly 60 years later, two Englishmen ascended to 31,000 feet (9,450 meters) in a balloon, observing numerous physiologic changes. At 19,000 feet (5,640 meters), the pulse increased to 100 beats per minute; at 19,500 feet (5,850 meters), breathing was affected, palpitations were perceived, hands and lips turned blue, and the crew experienced difficulty reading on board instruments. A sensation similar to seasickness was experienced at 21,500 feet (6,510 meters). At 28,500 feet (8,700 meters) there was extreme muscle fatigue and a period of insensibility lasting seven minutes.

BACKGROUND

It is important to review three essential topics before we can start to discuss the Stresses of Flight. A general understanding of the atmosphere, the physical gas laws and cabin pressurization will help illustrate how the human body responds to the atmospheric changes and will begin to explain several of the stresses of flight.

THE ATMOSPHERE

In order to have an understanding of how the physical gas laws may influence patient care it is important to first review the atmospheric composition. The atmosphere is made up of a collection of gases with uniform percentage up to an altitude of approximately 70,000 feet (21,319 meters). The largest percentage is nitrogen (78.08%), followed by oxygen at 20.95%. The remainder of the atmosphere includes argon, carbon dioxide, hydrogen, neon, and helium in very small percentages.

The atmosphere can be characterized several ways. It may be described by the temperature layers, which are
included within the atmosphere, or by the physiological zones that predict the effects of altitude on the human body. Many of these predictable effects are based upon atmospheric properties that can be observed at any given altitude. At any given point, the force or weight exerted by the atmosphere is the barometric pressure or atmospheric pressure. Temperature and volume changes will also be observed at the varying altitudes. Table 39-1 shows the relationship between altitude, barometric pressure, and temperature.

### Layers of the Atmosphere

The closest atmospheric layer to the earth is the Troposphere. In general, this layer extends to an altitude of 5 to 9 miles (8 to 14.5 km) above the surface of the earth. The altitude depends on the location of measurement, with the equator and the poles being the two extremes. This difference is due to the rising of heated air. In the troposphere, the temperature will decrease approximately 3-4°F (2°C) for every increase of 1,000 feet (305 meters) in altitude. In addition, a significant change in barometric pressure will start to be seen. Helicopter transport and a considerable amount of fixed-wing transport are performed within this layer. This is also the layer where most weather changes take place.

The Tropopause forms the boundary between the troposphere and the next layer, the Stratosphere. The stratosphere begins the upper atmosphere and contains the ozone layer. It extends from above the tropopause to about 31 miles (50 km) above sea level with the exact altitude varying between the equator and the poles. The temperature before this layer has achieved a constant (-69°F / -60°C), but gradually increases to reach -3°C. Barometric pressure continues to drop in the initial portion of this layer. No turbulence is experienced in the stratosphere. The majority of jet airplanes will routinely travel within the lower part of this layer at 35,000 to 45,000 feet (10,650 to 13,715 meters) altitude. The greatest concentration of ozone is located near the stratopause, which separates the stratosphere from the next layer, the mesosphere.

The mesosphere rises to the altitude of 53 miles (85 km) above the surface of the earth. In this layer, the temperature again drops as altitude increases, reaching -93°C. The mesopause separates the mesosphere from the next layer, the thermosphere. The mesosphere, mesopause, stratosphere, and stratopause together make up the middle atmosphere.

The thermosphere extends from beyond the mesopause to 373 miles (600 km) above the earth’s surface. It is the upper atmosphere and has increasing temperature as altitude increases. This increases up to 1,727°C due to heat from the sun. From 600 to 1,200 miles (960 to 1,200 km) above the earth is the Exosphere, which represents the vacuum of space.

The Ionosphere forms a protective shield from ultraviolet radiation and ranges from 50 to 600 miles (80 to 960 km) above the earth. This is a layer that overlaps with the highest levels of the middle atmosphere and the upper atmosphere of the temperature layers described above.

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<tr>
<td>34,000</td>
<td>10,363</td>
<td>3.63</td>
<td>43.2</td>
</tr>
<tr>
<td>36,000</td>
<td>10,973</td>
<td>3.30</td>
<td>42.6</td>
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<tr>
<td>38,000</td>
<td>11,582</td>
<td>3.05</td>
<td>42.0</td>
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<tr>
<td>40,000</td>
<td>12,192</td>
<td>2.72</td>
<td>41.4</td>
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<tr>
<td>42,000</td>
<td>12,802</td>
<td>2.47</td>
<td>40.9</td>
</tr>
<tr>
<td>44,000</td>
<td>13,411</td>
<td>2.24</td>
<td>40.4</td>
</tr>
<tr>
<td>46,000</td>
<td>14,021</td>
<td>2.04</td>
<td>40.0</td>
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<tr>
<td>48,000</td>
<td>14,630</td>
<td>1.85</td>
<td>39.5</td>
</tr>
<tr>
<td>50,000</td>
<td>15,240</td>
<td>1.68</td>
<td>39.0</td>
</tr>
</tbody>
</table>

Table 39-1: Altitude-Related Effects in the Earth’s Atmosphere

358 Chapter 39: Transport Physiology: A Reference for Air Medical Personnel
Physiological Zones of the Atmosphere

There are four physiological zones that make up the earth’s atmosphere. There are pressure changes that take place within these zones, which result in physiological impact.

The first zone is the Physiological Zone or Efficient Zone. It extends from sea level to approximately 12,000 feet (3,658 meters) with the barometric pressure dropping from 760 mmHg to 483 mmHg. This is the most acceptable zone for normal physiological function unless an individual acclimatizes to a higher altitude or supplemental oxygen is used. With prolonged exposure, acclimatization occurs, but minor problems may occur, especially if an individual continues to ascend, over exerts himself, or stays too long.

The Physiological Deficient Zone extends from 12,000 to 50,000 feet (3,658 to 15,240 meters) and exhibits a dramatic drop in both barometric pressure (from 483 to 87 mmHg) and in temperature. Normal physiological function will be seriously impaired at the upper limits of this zone, unless there is appropriate intervention. Most commercial and private aviation occurs in this zone and the physiological zone.

The remaining zones are the Partial Space Equivalent Zone and the Total Space Equivalent Zone. The Partial Space Equivalent Zone extends from 50,000 feet to 120 miles (15,240 meters to 192 km), where a pressurized environment is required to compensate for the barometric changes that can affect the body.

The Total Space Equivalent Zone, which extends from 120 miles (192 km) above sea level and beyond, represents “true space” and is where weightlessness occurs.

THE PHYSICAL GAS LAWS

A basic knowledge of the gas laws will help explain the changes the body will experience when exposed to different altitudes.

Boyle’s Law

Boyle’s Law relates to the expansion of gases. It states that when the temperature remains constant, the volume of a given mass of gas is inversely proportional to its pressure. An example is when an aircraft changes altitude. As an aircraft ascends and altitude increases, barometric pressure decreases and the volume of gas within an enclosed space expands. As the aircraft descends, the reverse is true. (Assuming temperature is constant.)

The formula for Boyle’s Law is: \( P_1V_1 = P_2V_2 \) —or- \( V_2 = \frac{P_1V_1}{P_2} \). By definition, \( P_1 \) = Initial Pressure; \( P_2 \) = Final Pressure; \( V_1 \) = Initial Volume; and \( V_2 \) = Final Volume.

As an aircraft ascends in altitude, the surrounding barometric pressure will decrease and, using Boyle’s Law, the volume of gas within an enclosed space will expand (Figure 39-1). As the aircraft descends from altitude, the reverse will be true.

Figure 39-1: Boyle’s Law

Using Boyle’s Law, gas expansion ratios can be calculated for various altitudes. At altitudes that helicopters normally fly (up to a few thousand feet, except in mountainous regions), the gas expansion will be relatively small (10 to 15%). At 8,000 feet (2,438 meters) above sea level, the gas expansion will be 30%. This altitude is an important consideration for unpressurized aircraft. This also represents the approximate cabin altitude for many pressurized aircraft flying at 35,000 to 40,000 feet (10,650 to 12,192 meters). Table 39-2 shows the relationship between altitude and gas expansion.

<table>
<thead>
<tr>
<th>Altitude (in feet)</th>
<th>Approx. Volume Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea level</td>
<td>1.0</td>
</tr>
<tr>
<td>3,000</td>
<td>1.1</td>
</tr>
<tr>
<td>5,000</td>
<td>1.2</td>
</tr>
<tr>
<td>7,000</td>
<td>1.3</td>
</tr>
<tr>
<td>10,000</td>
<td>1.5</td>
</tr>
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<td>15,000</td>
<td>1.8</td>
</tr>
<tr>
<td>18,000</td>
<td>2.0</td>
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<td>20,000</td>
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<tr>
<td>40,000</td>
<td>5.4</td>
</tr>
<tr>
<td>50,000</td>
<td>8.7</td>
</tr>
</tbody>
</table>

Table 39-2: Volume Ratio at Different Altitudes

* Refer to Table 1 for conversion from feet to meters
Clinically, Boyle’s law can affect any body cavity or piece of medical equipment that has an enclosed air space. Intravenous flow rates, the pressure in pneumatic anti-shock garments (PASG, also known as MAST pants), and endotracheal tube cuff expansion can all be altered. Body cavities that can be affected include the stomach, intestines, middle ear, and sinuses. Other potential spaces found in injuries and pathology can also be affected and need to be considered. These include, but are not limited to, a closed pneumothorax, pneumocephaly, pneumoenteritis, and subcutaneous emphysema. The effect of Boyle’s law on certain disease processes such as obstructive lung disease also needs to be considered.

An understanding of Boyle’s Law helps explain the mechanism by which air is exchanged between the atmosphere and the lungs. When an enclosed air space doubles in size, in this case the lungs, the pressure within the container will be reduced by one-half. As the chest expands and increases in size from the movement of the thoracic cage and diaphragm, pressure within the chest cavity will decrease, becoming less than the surrounding ambient pressure. As a result, air will rush in until the pressure within the lungs is again equal to the surrounding atmosphere.

**Dalton’s Law**

Dalton’s Law of Partial Pressure describes the pressure exerted by gases at various altitudes. It states that the total pressure of a gas mixture is the sum of the individual or partial pressures of all the gases within the mixture. Dalton’s Law can be represented as: $P = P_1 + P_2 + P_3 + \ldots + P_n$. By definition, $P = $ Total Pressure; and $P_1, P_2, \ldots, P_n = $ Partial pressure of gases in a mixture containing “n” gases.

Each gas will exert a pressure equal to its proportion of the total gaseous concentration within the total mixture of gases. At sea level total barometric pressure is 760 mmHg and the percentage of oxygen in the atmosphere equals 20.95%. The partial pressure of oxygen (PO$_2$) at sea level is: $PO_2 = 20.95\% \times 760$ mmHg = 159.22 mmHg.

The percentage of each gas within the atmosphere remains constant from sea level to 70,000 feet (21,319 meters). As the altitude increases and the total barometric pressure decreases, the partial pressure of the gaseous components will decrease, exerting less pressure. At an altitude of 10,000 feet (3,048 meters), the atmospheric pressure is 523 mmHg. While the percentage of oxygen remains 20.95%, the partial pressure of oxygen will decrease as follows: $PO_2 = 20.95\% \times 523$ mmHg = 109.56 mmHg (refer to Table 39-3).

The decrease in partial pressure at altitude is an important consideration for oxygen delivery into the body. A pressure differential is required for oxygen to cross the alveoli into the bloodstream. As a result of this decrease in the partial pressure of oxygen, less oxygen is transferred to the body (Figure 39-2). Newborns, especially preterm neonates, are more likely than adults to develop hypoxia as the partial pressure of alveolar oxygen falls during ascent. Although the usual alveolar-arterial difference in partial pressure of oxygen in adults is approximately 10 mmHg, the difference in newborns is much larger (approximately 25 mmHg). Therefore, a modest drop in PaO$_2$ will result in hypoxia in the newborn.

![Figure 39-2: Dalton's Law: Effects on Oxygen Transfer](image)

In addition, as altitude increases and pressure decreases, gas expansion causes the available oxygen to decrease as gas molecules move farther apart in a given volume of air. Therefore, less oxygen is available to enter the lungs with each breath (Table 39-4). The net result of these pressure changes is hypoxia. While this is not a problem for most people, those with chronic disease may be impaired. For example, a person with lung disease that has an oxygen saturation of 92% at sea level may drop their saturation into the 80s in a pressurized commercial aircraft and become symptomatic.

The data presented in the column labeled PaO$_2$ should be considered an approximation only, since in the clinical and transport settings, PaO$_2$ will vary with age, hemoglobin and underlying pathophysiology. The

<table>
<thead>
<tr>
<th>Gas</th>
<th>Percentage Within the Atmosphere</th>
<th>Partial Pressure (mmHg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>at Sea Level at 10,000 feet</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>78%</td>
<td>593 408</td>
</tr>
<tr>
<td>Oxygen</td>
<td>21%</td>
<td>160 110</td>
</tr>
<tr>
<td>Other Gases</td>
<td>1%</td>
<td>7 5</td>
</tr>
<tr>
<td>Total in the Atmosphere</td>
<td>100%</td>
<td>760 523</td>
</tr>
</tbody>
</table>

Table 39-3: Gases within the Atmosphere
actual equation is: \( A-a (O_2) = (FIO_2 \times 100) \times \left( P_{\text{aw}} - 47 \text{ mmHg} \right) - (P_{\text{aco}} / 0.8) - (P_{\text{ao}}) \). By definition: \( FIO_2 \) is the fraction of inspired oxygen; \( P_{\text{aw}} \) is the barometric pressure in mmHg; 47 mmHg represents the partial pressure of water at body temperature; and 0.8 is a “respiratory quotient fudge factor.” Because carbon dioxide displaces oxygen in the alveolus, the estimated alveolar carbon dioxide must be subtracted. The alveolar carbon dioxide is estimated by dividing the PaCO₂ by 0.8. Some references prefer to multiply the PaCO₂ by a respiratory quotient fudge factor of 1.25. The net result is the same.

**Henry’s Law**

Henry’s Law explains the solubility of gases within a liquid and states that “the quantity of gas dissolved in 1 cm³ of a liquid is proportional to the partial pressure of the gas in contact with the liquid.” The partial pressure of a gas and the solubility of the gas determine the amount of gas that will dissolve into a liquid. A carbonated beverage bottle or can is a common example of this law. With the cap on, the gas above the liquid creates an equilibrium with the gas dissolved in the liquid. When the cap is removed, there is a pressure decrease in the gas above the liquid, allowing the gas bubbles within the liquid to come out of solution and become released.

**The bends**, a type of decompression sickness, provide another example of Henry’s Law. A SCUBA (Self Contained Underwater Breathing Apparatus) diver ascending too quickly can cause nitrogen gas to come out of solution in the body and form bubbles in tissue, joints, and blood. A specific altitude threshold cannot predict a clinical response to Henry’s Law and the probability of developing a decompression sickness. However, there is evidence of altitude decompression sickness occurring among healthy individuals at altitudes below 18,000 feet (5,486 meters) who have recently been scuba diving. Exposure to altitudes between 18,000 feet and 25,000 feet (5,486 to 7,620 meters) has shown a low occurrence of a decompression sickness. Most cases occur among individuals exposed to altitudes greater than 25,000 feet (7,620 meters). The higher the altitude a person at risk is exposed to, the greater the risk of developing decompression illness.

**Henry’s Law further explains the gas transfer between the alveoli and the blood. Gases have a tendency to move from an area of higher concentration to that of lower concentration. As the partial pressure of a gas changes (Dalton’s Law), the amount of that gas in solution will also change.**

**Charles’ Law**

Charles’ Law states that when pressure is constant, the volume of a gas is very nearly proportional to its absolute temperature. As the temperature increases, gas molecules will move faster and the volume of gas will increase. The formula for Charles Law is: \( V_1 / V_2 = T_1 / T_2 \). By definition: \( V_1 = \text{Initial Volume}; T_1 = \text{Initial Absolute Temperature}; T_2 = \text{Final Absolute Temperature}; V_2 = \text{Final Volume}; \) Absolute temperature = temperature in °C + 273°C. This
was discovered during the rise of use of hot air balloons in eighteenth-century France (which also played a role in the beginning of air medical transport).

**CABIN ALTITUDE**

The creation of an artificial atmosphere or cabin altitude represents the first protection against the influences of a changing altitude. In a pressurized airplane, compressed air is pumped into the cabin to create and maintain a cabin altitude that is significantly less than the actual flight altitude. There are three factors that work together to maintain a constant pressure within the airplane: the amount of compressed air that can be introduced based upon the airplane’s fuselage construction, a known leak rate of air from the airplane, and a controlled outflow of air.

Aircraft manufacturers specify the Maximum Pressure Differential for each aircraft, which refers to the maximum pressurization limit, based upon the fuselage construction of the airplane. Using the known atmospheric pressure at the cruising altitude and the Maximum Pressure Differential, it is possible to calculate the artificial cabin altitude that can be achieved. The difference between the “outside” atmospheric pressure at flight altitude and the artificial “inside” cabin pressure is the Cabin Differential Pressure. The cabin pressure can be adjusted by the pilot from zero up to the Maximum Pressure Differential (as determined by the aircraft manufacturer). Therefore, the cabin altitude may vary as the flight altitude changes. At flight altitudes of 30,000 to 40,000 feet (9,144 to 12,192 meters), pressurized aircraft can often create an internal cabin altitude of 7,000 to 8,000 feet (2,134 to 2,438 meters). This corresponds to an interior cabin pressure equal to approximately 3/4 atm (565 mmHg), which also prevents pressurized airplanes from expanding and contracting too much as they change altitude. Flying at lower altitudes, high differential cabin pressure aircraft have the ability to create a cabin pressure that exceeds ground altitude pressures. This may be beneficial when transporting a patient suffering from decompression illness. The cabin altitude should be determined by patient requirements as well as by the destination or departing altitude when this is possible.

While there are obvious advantages to a pressurized air cabin, a well trained medical crew must also be aware of the possibility of a sudden loss of cabin pressurization (decompression), the possible causes of decompression, and the predictable consequences. A malfunction of the pressurization equipment or aircraft structural damage (i.e., a cracked window or foreign object) may result in a loss of cabin pressure or decompression. The effects of decompression will depend upon several factors: total cabin volume, size of the structural defect in the hull, flight altitude, and the pressure differential between the flight altitude and the cabin altitude.

During a Rapid Decompression, there is a loss of pressure, within 1 to 3 seconds, through a large defect. This results in an explosive noise, a rapid temperature drop and flying debris towards the hole. The aircraft will fill with fog due to moisture condensation in the expanding cabin atmosphere. This fog may be mistaken for smoke within the cabin. Crewmembers, patients, and equipment that are not properly restrained may be tossed about the cabin or even pushed out if they are near a large cabin defect.

A rapid drop in the cabin PO$_2$ quickly leads to crewmember hypoxia, which is the most important clinical consequence of rapid decompression at high altitude. Oxygen tension in the blood will drop very quickly. Depending on the altitude, a person’s effective performance may quickly be compromised. In a rapid decompression, supplemental oxygen must be applied first to the pilot and the medical crew and finally to the patient. Another significant event caused by rapid decompression will be the rapid expansion of air within an enclosed space. All catheters, chest tubes and nasogastric tubes should then be unclamped. (Theses related topics are discussed in greater detail in the next section.)

Helicopters are unpressurized and cannot create an artificial atmosphere. Therefore, these vehicles offer nothing to prevent the effects of a changing altitude, since the cabin altitude will be the same as the actual flight altitude. Small unpressurized airplanes also offer no benefit in combating the effects of the gas laws and therefore are generally limited to altitudes less than 10,000 feet (3,048 meters).

It is often thought that only altitudes above 8,000 feet (2,438 meters) could impact the patient or crew, but this is not always the case. Consistent with the properties of Boyle’s Law, crew members or patients flying in helicopters or unpressurized airplanes with ear problems, sinus problems, or upper respiratory infections may feel the effects of barometric pressure changes with as little as a 1,000 to 2,000-foot (305 to 610 meters) change in altitude. Up to 25% of persons who rapidly ascend to an altitude of 8,000 feet (cabin altitude of 8,000 feet or actual altitude of 8,000 feet in an unpressurized aircraft) will become symptomatic. Nearly everyone exposed to an altitude of 12,000 feet (3,658 meters) will develop symptoms, commonly referred to as “altitude sickness.”
Principles and Direction of Air Medical Transport

STRESSES OF FLIGHT AND TRANSPORT

To better understand the impact that various stresses may have upon both the patient and the medical crew, it is important to appreciate the link between "stress" and work performance. Stress results from a perceived imbalance between a demand and the ability to meet that demand. Stress can cause fatigue and suboptimal work performance. However, familiarity with a stressor reduces the physiological impact of the stress and consistent practice or familiarity with a task can reduce the behavioral impact of the stress.

Patient simulations in ACLS, ATLS, and continuing education, as well EMS disaster drills and downed aircraft drills, are all designed to familiarize the participants to the "task" being practiced. Similarly, a thorough knowledge and understanding of the stresses of transport may prevent related complications during either helicopter or fixed-wing medical transport.

There are two types of stresses associated with the aviation environment and air medical transport. They are the Stresses of Transport and Self-Imposed Stresses. It is important to realize that these stresses are cumulative and may lead to significant physiological and emotional compromise. Various authors and organizations have identified numerous stresses of flight. In general, nine stresses of flight are identified. These include hypoxia, barometric pressure, thermal considerations, humidity/dehydration, noise, vibration, gravitational forces, third spacing, and fatigue.

The impact of these stresses will vary with the mode of transportation. Vibration, noise, and turbulence are generally more severe in helicopters than in other forms of transportation. Many of these stresses may also affect ground transport. Therefore, even transport teams that never participate in helicopter or fixed-wing transport will benefit from a basic knowledge of the stresses. Of these nine stresses, those that may have the greatest effect on ground transport are noise, vibration, temperature, gravitational forces, and fatigue.

Any significant altitude change can expose the patient and transport team to additional physiologic stresses. Three major factors influence the incidence, onset, and severity of complications that can be experienced during air transport: rate of ascent (or descent); the altitude achieved; and the length of stay at that altitude. Varying severity of complications occurs when any of these factors, or a combination of them, exceeds an individual's ability to adapt to the new environment. Previously compromised patients and young children, because of their physiologic differences, are at greater risk for developing many altitude-related illnesses. For children, the severity of symptoms will decrease with increasing age, but it is essential to always watch for the onset of symptoms.

HYPOXIA

Hypoxia may be defined as an oxygen deficiency in body tissues sufficient to cause impairment of physiological function. In air medical transport, the most threatening factor of hypoxia is its insidious onset. The crew may be involved in flight activities and not notice the onset of symptoms.

Classification of Hypoxia

There are four physiologic classifications of hypoxia that can be described based upon their various etiologies: Hypoxic Hypoxia; Hypemic Hypoxia; Stagnant Hypoxia; and Histotoxic Hypoxia.

Hypoxic (Altitude) Hypoxia results from an inadequate gas exchange at the alveolar-capillary membrane. A deficient oxygen supply to the blood results in an oxygen deficiency to the tissues. Common causes include an airway obstruction, ventilation/perfusion defect, or an inadequate oxygen partial pressure in inspired air. Hypoxic hypoxia represents the most common cause of hypoxia encountered at altitude and may become apparent above 10,000 feet (3,048 meters). With no compensatory mechanism (supplemental oxygen or a pressurized cabin), blood oxygen saturation at sea level of 98% will decline to 87% at 10,000 feet (3,048 meters) and 60% at 22,000 feet (6,706 meters).

Hypemic (Anemic) Hypoxia is caused by a reduction in the oxygen-carrying capacity of the blood. Causes include anemia, blood loss, dyshemoglobinemia, carbon monoxide poisoning, certain drugs, and excessive smoking.

Stagnant Hypoxia results in oxygen deficiency in the body due to poor circulation. This may happen when cardiac output does not satisfy tissue requirements or from venous pooling, arterial spasm, occlusion of a blood vessel, or long periods of positive pressure breathing or ventilation.

Histotoxic Hypoxia is the inability of the body tissues to utilize available oxygen. In this situation, there is adequate oxygen on hand, but the body tissues are unable to utilize the available oxygen. Carbon monoxide and cyanide poisoning, alcohol ingestion, and narcotics may all result in this form of hypoxia.

It should be noted that all the above types of hypoxia can occur as a result of high altitude exposure, but the most serious concern during air medical transport is hypoxic or altitude hypoxia.
Signs and Symptoms of Hypoxia

No one is exempt from the effects of hypoxia and, regardless of the cause, the symptoms are the same. The onset and severity of symptoms may vary with individuals. Some persons may tolerate a few thousand feet more altitude than others. All patients and crew members will begin to experience symptoms of mild hypoxia if exposed to a high enough altitude. However, transport in a pressurized cabin will normally eliminate or reduce the potential for hypoxic complications.

There are many factors that may influence an individual’s susceptibility to hypoxia. Physical activity, physical fitness, metabolic rate, diet, nutrition, emotions, and fatigue will all influence one’s threshold for hypoxia. A physically fit individual normally will have a higher tolerance to altitude related problems. Also, increased physical activity will raise the body’s demand for oxygen and cause a more rapid onset of hypoxia. Alcohol ingestion may create histotoxic hypoxia. Smoking produces carbon monoxide that reduces the blood’s capacity to combine with oxygen. Exposure to temperature extremes will increase a person’s metabolic rate, resulting in increasing oxygen requirements and reducing the hypoxic threshold.

Many predisposing medical illnesses will be exacerbated at altitude, including pneumonia, COPD, acute asthma, pneumothorax, cardiac disease and heart failure, shock, and blood loss. Children and individuals with low tidal volume are less able to respond to the hypoxic insult, and therefore are more prone to develop related complications.

Respiratory System

An increased rate and depth of respiration is the initial respiratory system response to hypoxia. The threshold for increased ventilation is approximately 4,000-5,000 feet (1,219 to 1,524 meters) elevation. At an altitude of approximately 8,000 feet (2,438 meters), an arterial oxygenation saturation of 93% is experienced. The maximum response occurs at approximately 22,000 feet (6,706 meters) when the minute ventilation (respiratory rate/minute multiplied by tidal volume) will be nearly doubled. Most of this increase is secondary to a change in tidal volume rather than respiratory rate. Hyperventilation will result in a reduction of the partial pressure of carbon dioxide (PaCO₂), causing respiratory alkalosis and a shift of the oxyhemoglobin dissociation curve to the left. The result will allow an increased binding of oxygen with hemoglobin for transport to the tissues.

Hypoxia will also act as a significant vasoconstrictor of the pulmonary vascular bed, resulting in an elevation of the pulmonary arterial pressure and an increased workload on the right side of the heart. Acidosis is also a potent pulmonary vascular vasoconstrictor. Providing supplemental oxygen acutely may relieve hypoxia, but may simultaneously decrease alveolar ventilation, increasing acidosis and sustaining pulmonary vasoconstriction.

An important consideration during air medical transport involves medications that the patient may be given. Central nervous system depressants may inhibit the respiratory response to hypoxia that normally occurs at altitude. This emphasizes the need to recognize the early symptoms of hypoxia, to properly monitor the patient, and to aggressively treat patients who are hypoxic.

Central Nervous System

Cerebral hypoxia may begin when the PO₂ falls to 50-60 mmHg. Hypoxic effects at higher oxygen partial pressures may also occur, depending on an individual’s physical condition (pre-disposing illness) and their activity level. The potent vasodilatory effects of hypoxia will overcome the hypocapnic vasoconstriction and result in an increased cerebral blood flow.

The hypoxic states result in a decreased ability to function. The brain and the eyes will be significantly affected due to the high oxygen requirements of these organs. Supplemental oxygen should be used for any patient with a recent eye injury, eye surgery, or progressive retinal disease.

The initial CNS signs and symptoms that may be observed are excitation, talkativeness, euphoria, hyperactivity, and restlessness. The progressive effects of CNS hypoxia are directly proportional to the severity and duration of the hypoxic event. As CNS hypoxia persists, a patient or crew member will exhibit a more limited attention span, impaired memory, diminished sensory input (sound, taste), deterioration of visual field and/or depth perception, depression, impaired judgment, and progressive mental confusion. If untreated, the patient will eventually become unconscious, cerebral activity will cease and death will follow.

Unconsciousness due to hypoxia is a serious consideration in fixed-wing transport at higher altitudes. Effective Performance Time ("EPT") refers to the amount of time an individual will be able to execute critical functions in an oxygen deficient environment. The term Time of Useful Consciousness ("TUC") is often used interchangeably with Effective Performance Time, which applies to pilots as well as medical crew members, when subjected to an interruption of the oxygen supply or exposure to an oxygen-poor environment. Both patient care and safety of the transport could be seriously compromised if the crew is unable to initiate preventative or corrective action in flight in the setting of an oxygen deficient environment.
As with the variable onset of symptoms, there are several factors that can influence EPT. Effective Performance Time will decrease at higher altitudes. It will also decrease with faster rates of ascent, with increased physical activity, and with fatigue. The use of tobacco, ingestion of alcohol, or certain medications will also shorten the EPT. The most dramatic effect on EPT is rapid decompression. The sudden loss of the artificial cabin altitude (pressurized aircraft) will quickly result in an oxygen deficient environment.

The Effective Performance Time for an individual exposed to the varying altitudes is shown in Table 39-5.

<table>
<thead>
<tr>
<th>Altitude in Feet</th>
<th>Effective Performance Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>12,000 to 20,000</td>
<td>30 min or more</td>
</tr>
<tr>
<td>22,000</td>
<td>5 to 10 min</td>
</tr>
<tr>
<td>25,000</td>
<td>3 to 5 min</td>
</tr>
<tr>
<td>28,000</td>
<td>2.5 to 3 min</td>
</tr>
<tr>
<td>30,000</td>
<td>1 to 2 min</td>
</tr>
<tr>
<td>35,000</td>
<td>30 to 60 sec</td>
</tr>
<tr>
<td>40,000</td>
<td>15 to 30 sec</td>
</tr>
<tr>
<td>45,000</td>
<td>9 to 15 sec</td>
</tr>
</tbody>
</table>

*Refer to Table 1 for conversion from feet to meters

Cardiovascular System

The cardiovascular system is relatively resistant to hypoxia compared to the respiratory and central nervous systems. The heart rate will begin to increase at an altitude of approximately 4,000 feet (1,219 meters) and will achieve a maximum rate at approximately 22,000 feet (6,706 meters).

Cardiovascular system response to hypoxia may be observed in two phases. An initial increase in cardiac output will be caused by an escalation in the heart rate and selective vasoconstriction. A further increase in cardiac activity will then require more oxygen and the already hypoxic myocardium will respond with a decrease in heart rate, hypotension, and/or arrhythmias.

Physiologic Stages of Hypoxia

Previously, four physiologic classifications of hypoxia were defined. Another portrayal of hypoxia is to review the physiologic stages of hypoxia, which are predictable at different altitudes. Symptoms associated with each stage can help explain the hypoxic phenomenon.

Indifferent Stage

The Indifferent Stage of Hypoxia is characteristic of an exposure from sea level to an altitude of 10,000 feet (3,048 meters). Typically oxygen saturation will range from 90-98%, if there are no complications. The heart and respiratory rates will increase to combat the effects of hypoxia. At approximately 4,000-5,000 feet (1,219 to 1,524 meters) there may be an onset of blurred vision and tunnel vision. At 5,000 feet (1,524 meters), a 10% reduction in night vision may be noted and by 10,000 feet (3,048 meters) the night vision can decrease by as much as 28%. Throughout the Indifferent Stage, the individual is usually unaware of their symptoms and there may be no noticeable impairment.

Compensatory Stage

Despite the apparent significance and variety of symptoms seen in the Compensatory Stage, this stage of hypoxia may not be readily identified. In the Compensatory Stage, a crew member or patient subjected to an altitude between 10,000-15,000 feet (3,048 to 4,572 meters) will experience all the same symptoms as in the Indifferent Stage, but with a more noticeable increase in respiratory rate, heart rate, systolic blood pressure, and cardiac output. Oxygen saturation of an uncompromised person will be between 80%-90%. Night vision will decrease by 50%. Subjectively, an individual may begin to experience nausea, dizziness, listlessness, headache, fatigue, air hunger, apprehension, and hot and cold flashes. CNS symptoms will be evident after a 10 to 15 minute exposure at 12,000-15,000 feet (3,658 to 4,572 meters). Poor judgment, decreased efficiency, impaired coordination, and increased irritability may be seen.

Disturbance Stage

During the Disturbance Stage, which typically can be seen at an altitude of 15,000 to 20,000 feet (4,572 to 6,096 meters), oxygen saturation will be between 70-80%. Individual compensatory mechanisms and physiological response can no longer compensate for the O₂ deficiency and individuals are usually aware of the hypoxic symptoms found within this stage. Some people, however, may suffer a loss of consciousness without ever experiencing the subjective symptoms.

Subjective symptoms of air hunger, headache, amnesia, decreased level of consciousness, nausea and vomiting (especially in children) are more pronounced. Objectively, the senses are diminished. There may be weakness, numbness, tingling and decreased sensation of touch and pain, and visual acuity is more impaired. Reaction time, short-term memory, coordination, speech, and handwriting may be greatly impaired. Personality traits may be altered with evidence of aggressive behavior, belligerence, euphoria, over confidence, or depression. Cyanosis may be noted, but should not be relied upon as a prominent clinical indicator of the disturbance stage.

Patients who present to the Emergency Department with subjective complaints and significant signs of hypoxia often fall into this stage of hypoxia.
Critical Stage

The Critical Stage represents the most serious stage of hypoxia. Previous symptoms that may have been overlooked can no longer be ignored. Objective findings may now escalate to include an inability to remain upright, jerking of upper limbs, seizures, rapid unconsciousness, coma, and death. At an altitude of 20,000 to 25,000 feet (6,096 to 7,620 meters), oxygen saturation drops between 60-70%.

Treatment of Hypoxia

In air medical transport, the primary “treatment” for hypoxia should be directed towards its prevention. While altitude-related patient hypoxia is a concern, the routine use of pulse oximetry and supplemental oxygen minimizes this hazard. Recognition of symptoms, both subjective and objective, becomes the next priority. Having the capabilities to closely monitor the patient during transport, including physical exam, pulse oximetry, and endtidal CO₂ detector is critical. It is also advisable for the medical crew to be able to monitor cabin altitude.

Whether the hypoxia is secondary to altitude or any other etiology, supplemental oxygen remains the key to its treatment.

The goal of oxygen therapy is to increase the alveolar concentration of oxygen, decrease the myocardial workload, and decrease the demand on the pulmonary system.

The Oxygen Adjustment Equation (also referred to as the Altitude Oxygen Requirement Equation) can be used to calculate the FIO₂ required for any given cabin altitude or destination altitude. The formula is: (FIO₂ x \(BP_1\)) + \(BP_2\) = FIO₂ required. By definition, FIO₂ is the patient’s current fraction of inspired O₂; \(BP_1\) represents the current barometric pressure; \(BP_2\) is the altitude or destination barometric pressure; and FIO₂ required will be the new FIO₂.

For example, a patient is currently receiving an FIO₂ of 44% at a referring hospital at sea level. This patient will be transported in an aircraft at a cabin altitude of 7,000 feet (2,134 meters). The new required FIO₂, necessary to achieve the same oxygen saturation will be: \((.44 \times 760 \text{ torr}) + 586 \text{ torr} = .57\). This FIO₂ can be achieved either with a simple mask at 7-8 liters per minute or with a partial non-rebreather at 6 liters.

Another consideration using a modification of this equation would be to calculate the Maximum Altitude of Equal Oxygenation. For patients with high oxygen requirements the air medical crew may choose to alter the oxygen delivery to 100% and determine the maximum cabin altitude that can be tolerated by the patient. The equation is: Initial FIO₂ \times \(BP_1\) + Final FIO₂ = \(BP_2\). By definition: Initial FIO₂ = Patient’s current fraction of inspired oxygen; Final FIO₂ = 100% = 1; \(BP_1\) = Current barometric pressure; \(BP_2\) = Destination or altitude barometric pressure.

For example, a patient on 80% O₂ at a referring hospital in a city that is at 1,000 feet (305 meters) above sea level will be transported on 100% oxygen. The Maximum Altitude of Equal Oxygenation can be calculated: \(80 \times 733 = BP_2 = 586 \text{ mmHg}\). Referring to Table 1, a barometric pressure of 586 mmHg is equal to an altitude of 7,000 feet (2,134 meters).

These calculations are useful during air medical transport. Its use may seem less important when using pulse oximetry. However, pulse oximetry may not adequately reflect the patient’s oxygen requirements. When monitoring the patient with pulse oximetry, crewmembers tend to rely on monitor readings to alter therapy, but it may not be the most reliable. Therefore, the routine use of the oxygen adjustment equation is recommended.

If supplemental oxygen is on and hypoxia is still evident, the medical crew must consider a malfunction of the on-board oxygen system, deterioration in the patient’s condition, or that the patient cannot tolerate the change in barometric pressure. In the setting of hypoxemia, increasing FIO₂ levels and, in some circumstances, the addition of PEEP easily compensates for the hypoxic effects of altitude. However, in the rare patient who is on maximal oxygen support, flight at lower altitudes may allow the artificial cabin pressure to approach sea level, resulting in an increase in the partial pressure of oxygen. Increasing the artificial cabin altitude by raising the cabin pressurization may also be beneficial when this is mechanically possible. At times, a combination of alternatives may be necessary.

Hypoxia is more of a concern for the pilots and crewmembers who generally are not monitored. During air medical transport at high altitudes, it may be advantageous to check oxygen saturation of the crew. In addition, the Federal Aviation Administration (FAA) has specific regulations addressing the use of oxygen. The Federal Aviation Regulations, which apply to on-demand air taxis (and include patient transport), require pilots to use supplemental oxygen if they are flying at cabin altitudes above 10,000 feet (3,048 meters) for more than 30 minutes and any time above 12,000 feet (3,658 meters). At cabin pressure altitudes above 15,000 feet (4,572 meters), each occupant of the aircraft must use supplemental oxygen.

BAROMETRIC PRESSURE

The effects of altitude on the human body and some medical equipment result directly from the effects of the gas laws. The impact of barometric pressure changes can
affect the medical crew, patient and equipment in many ways. There are several types of “injuries” that can develop with respect to the body’s physiologic response to changing pressures. These injuries can result in actual tissue damage or may only cause pain to the individual.

There are three distinct terms often used when discussing the effects of barometric pressure. *Dysbarism* represents the general topic of pressure-related injuries. Injuries that are a direct result of the mechanical effects of a pressure differential are referred to as *barotrauma*, and the complications related to the partial pressure of gases and dissolved gases are called *decompression sicknesses*.

There are three mechanisms by which barometric pressure affects the body. The first follows Boyle’s Law, which deals with gas within an enclosed space and changes in ambient pressure. If air is unable to escape, a positive pressure develops, which may result in a rupture or the compression of adjacent structures. The second mechanism follows Henry’s Law, corresponding to the release of gas dissolved in blood. The third mechanism applies to barometric changes in an underwater environment (i.e., scuba diving) and its effects on tissue concentrations of various gases. This latter topic will not be discussed in this chapter.

**Barotitis Media**

Barometric pressure changes can result in disturbances of the middle ear. The tympanic membrane separates the middle ear from the outer ear, while the eustachian tube forms a connection between the middle ear and the external atmosphere via the nasopharynx. The eustachian tube usually functions as a one-way valve, allowing gas to escape but not allowing it to return to the middle ear. Gas will expand in the middle ear behind the tympanic membrane as altitude increases. During ascent, gas will escape through the eustachian tube every 500-1000 feet (150 to 305 meters), or when there is a pressure differential of approximately 15 mmHg, allowing for equalization of pressures between the middle ear and the surrounding atmosphere. As altitude decreases, the gas within the middle ear contracts, creating a negative pressure within the middle ear and pulling the tympanic membrane inward. Under normal circumstances, the eustachian tube will not allow the passive movement of air into the middle ear. However, the eustachian tube can be actively opened, allowing equalization with the middle ear by using positive pressure originating from the nasopharynx or by using the jaw muscles.

Under normal situations, pressure in the middle ear is equalized without incident. However, if a person has an upper respiratory infection (URI), allergies, or sinus problems, the eustachian tube may be obstructed and equalization may be restricted. As a result, flying is not recommended for crewmembers who have a URI, sore throat, or ear infection.

*Barotitis media*, also referred to as *middle ear squeeze* or *ear block*, can affect both the crew and patient. A fullness in the ears may occur as equalization takes place during ascent. Severe pain, tenderness, vertigo, nausea, perforation of the eardrum, and bleeding can occur during either ascent or descent if pressures are not equalized. Hearing loss may occur as a result of decreased vibration of the eardrum. Typically, individuals will become symptomatic when the pressure differential approaches 100 mmHg. The severity of symptoms will depend upon the individual’s initial condition, rate of ascent or descent, and individual compensatory mechanisms.

Air medical crewmembers should be familiar with the early symptoms of barotitis media. The treatment of barotitis media is directed toward the equalization of pressure between the middle ear and the atmosphere. Attempts should be made to equalize pressures before the symptoms become severe. Equalization may be accomplished by yawning, swallowing, or performing the Valsalva maneuver. The Frenzel maneuver is another suggested treatment. This maneuver is performed by forcing closed the glottis and mouth while contracting the superior pharyngeal constrictors and the muscles of the floor of the mouth. The use of a topical vasoconstrictor nasal spray may be beneficial when used about 15 minutes before descent. If there is concern for barotitis media, patients who are asleep should be awakened 5 minutes before descent, so they can swallow more frequently. For infants, consider giving a bottle during takeoff and landing. While this may reduce the likelihood of barotitis media, it may increase the incidence of GI distress after takeoff due to increased swallowing of air.

A slow descent from altitude, 500 feet/minute (150 meters/minute), is always recommended to minimize the onset of symptoms. If the descent is too rapid, the pilot may have to increase altitude again to allow equalization of pressure in the middle ear before attempting to descend again.

If pain persists after a flight, decongestants and analgesics may be used. Individuals who remain symptomatic should refrain from further altitude exposure until all signs and symptoms have resolved. Erythema of the tympanic membrane (TM) usually resolves within 1 to 3 days. It will take 2 to 4 weeks when there is blood behind the TM. A perforated tympanic membrane should be allowed to heal before flying again. This may take several days to weeks.
Barotitis Externa

The external auditory canal is normally a patent, air-filled cavity that communicates with the surrounding environment. If the external canal is obstructed, the enclosed air space will be subject to the increased ambient pressure during ascent to altitude, resulting in an external ear squeeze or barotitis externa. This obstruction can be due to cerumen, earplugs, or other foreign bodies. For this reason, tightly fitting ear plugs are not recommended during take-offs, landings, or significant changes in altitude.

Barosinusitis

Normally air can pass in and out of the sinus cavities without difficulty and the effects of barometric pressure will be minimal. However, if a person has a cold or sinus infection resulting in swelling of the mucous membrane lining, air may be trapped, which will expand as altitude increases. This can also occur during descent, with swollen mucosa not allowing air into the sinuses, resulting in increasing mucosal edema. This is commonly referred to as sinus squeeze. Failure of the air-filled frontal or maxillary sinuses to equilibrate results in pain or pressure above, behind or below the eyes. Pain may persist for hours and may be accompanied by a bloody nasal discharge or epistaxis. The ethmoid and sphenoid sinuses rarely contribute to this type of barotrauma.

The treatment for barosinusitis is similar to the treatment of barotitis media, with the most effective being the use of a vasoconstrictor nasal spray and returning to a higher altitude.

Barodontalgia

Air trapped in dental fillings, caries, abscesses or crowns may result in a severe toothache, which is most common during ascent. This type of barotrauma is referred to barodontalgia or tooth squeeze. This is often associated with recent dental extraction, dental fillings, periodontal infection, periodontal abscess, or tooth decay. While this is a rare problem, the pain can be very severe. Treatment should include preventative dental care, descending to a lower altitude and pain control. Following dental procedures, a minimum of 24 hours is advised before air transport.

Barogastralgia

Barogastralgia refers to the effects that barometric pressure change will have on the gastrointestinal (GI) system. Under normal circumstances, the stomach and intestines normally contain a variable amount of gas (up to 1,000 cc in an adult) at a pressure approximately equivalent to the surrounding atmospheric pressure. The stomach and large intestine contain considerably more gas than does the small intestine. At 18,000 feet (5,486 meters), the volume of gas in an enclosed expandable space will double, but symptoms usually do not become severe until an altitude of 25,000 feet (7,620 meters), when the volume of gas triples.

As gas expansion occurs on ascent, an individual may experience discomfort, bloating, abdominal pain, nausea, vomiting, belching, flatulence, shortness of breath, or hyperventilation. Significant distention of the abdominal contents may result in venous pooling which may lead to syncope. In addition, tachycardia, hypotension, and syncope may result from a vasovagal response to severe pain.

Barogastralgia is rarely a serious problem. However, ingesting a large amount of carbonated beverage, chewing gum (and swallowing air), eating large meals, and pre-existing GI problems may all increase the amount of gas in the intestines. Crying children and infants who are feeding tend to swallow an increased amount of air. To prevent intestinal complications from gas expansion, it is recommended to avoid carbonated drinks, gas producing foods, and large meals. Wearing clothes that are loose and non-restrictive may also be beneficial. Patients with a bowel obstruction or recent abdominal surgery must have a patent and unclamped nasogastric tube placed prior to transport. After a major surgical procedure, air trapping could persist and it is advisable to delay high altitude fixed-wing transport for 24-48 hours.

Barometric Effects on the Respiratory System

In addition to hypoxia, which has already been addressed in detail, special attention should be paid to the patient with a suspected or documented pneumothorax. A patient with an existing pneumothorax is prone to further collapse at altitude due to expansion of the trapped gas. Once a chest tube is placed, most patients can be safely transported, while being carefully monitored for evidence of hypoxia or malfunction or occlusion of the chest tube. Any patient who is artificially ventilated must be watched for the possible development of a tension pneumothorax.

During helicopter transport from the scene of an accident, it may not always be possible or practical to place a chest tube prior to transport. With normal ascent of 1,000 to 2,000 feet (305 to 610 meters), the barometric pressure change will be minimal and the change in volume of the pneumothorax will be less than 10%. If this were the only factor that might change, the patient may not be adversely affected. It is essential, however,
for the crew to closely monitor the patient for any clinical deterioration during transport.

Barobariatrauma

Barobariatrauma is a potential complication of barometric changes in the presence of obesity. Adipose tissue has a high concentration of nitrogen. Under barometric pressure changes, the adipose cell membrane may weaken and nitrogen can be released into the blood stream. Large concentrations of lipids can also be released, resulting in fat emboli.

The symptoms of barobariatrauma will be similar to those seen with decompression sickness or with fat emboli. Crew members should observe an obese patient for severe dyspnea, chest pain, petechia in the neck, shoulders or axilla, pallor and tachycardia.

Placing an obese patient on 100% oxygen for approximately 15 minutes prior to air medical transport could minimize the potential side effects of barobariatrauma. This will help remove nitrogen from the patient, reducing the risk by approximately 50%.

Considerations during Pregnancy

Fetal hypoxia may be a concern during air medical transport of pregnant patients or for pregnant flight crew members.

However, the results of available research suggest that no significant risk is associated with air medical transport of a pregnant woman or a fetus. The arterial partial pressure of oxygen in the fetus is significantly lower than that of the mother. A healthy fetus at sea level has an arterial oxygenation (PaO₂) of 32 mmHg in the umbilical arterial circulation while the PaO₂ of the mother will be approximately 100 mmHg. At an altitude of 8,000 feet (2,438 meters), the PaO₂ of the mother will drop to 64 mmHg and the oxygen saturation will be approximately 90%. The fetal PaO₂ will drop only from 32 to 25.6 mmHg. In addition to the lower partial pressure of arterial oxygen in the fetus, the oxygen dissociation curve for fetal hemoglobin differs from that for mature hemoglobin. Consequently, fetal hemoglobin is more fully saturated at a lower PaO₂ than is the hemoglobin of the mother.

Barometric Effects on Medical Equipment

Air enclosed within a given space of any piece of medical equipment will be subject to the changes in atmospheric pressure. Endotracheal tube cuffs will be affected by the significant change in altitude and should be evaluated to prevent balloon rupture or excessive pressure on the tracheal wall during ascent, as well as for an inadequate air seal on descent. Replacing the air in the ET tube cuff with water will eliminate this potential complication during air medical transport. The air in IV containers will expand on ascent resulting in an increase in the IV flow. On descent, the IV will slow when the air volume is decreased. Military antishock trousers (MAST), pants, and pneumatic splints may also be affected by pressure changes. At altitude, a compartment syndrome may develop from over inflation and distal circulation may be compromised. On descent, inadequate support may occur from inadequate air pressure in the pneumatic splints. A change in blood pressure (hypotension) may occur on descent or distal circulation may be compromised during ascent.

Decompression Sickness

A loss of cabin pressurization may result in a variety of decompression sicknesses, as gas dissolved in blood is released. The altitude threshold for decompression sickness is 18,000 feet (5,486 meters) but is rarely a problem under 25,000 feet (7,620 meters), unless there has been recent exposure (within 24 hours) to compressed gas (e.g., scuba diving). An exposure of 30 minutes to 3 hours at altitudes from 26,000 - 47,500 feet (7,925 to 14,467 meters) will result in a 1.5% incidence of decompression sickness, with the severity increasing with increased altitude and prolonged exposure.

There are two types of decompression sickness. The first deals with trapped gas (gas in various body cavities) and follows Boyle’s Law. This is also known as baro-trauma. These symptoms occur rapidly and have already been described. The second decompression sickness is related to evolved gases and follows Henry’s Law (gas dissolved in blood is released). These symptoms do not occur for a considerable amount of time. This is rarely a problem below an altitude of 20,000 feet (6,096 meters), and at 35,000 to 40,000 feet (10,670 to 12,092 meters) it will take about 20 minutes for the average individual to develop severe or incapacitating symptoms.

The bends refers to a musculoskeletal syndrome involving the joints and is caused by the release of nitrogen gas from the blood into the tissues surrounding the joint. A sharp, throbbing, or dull ache is a common presentation. In addition, there may be associated numbness, tingling, or other vague complaints. The most common joints affected are the shoulder and elbows in recreational divers. In technical divers and aviators, knees and hips tend to be the most commonly affected joints. Symptomatic relief may be obtained by splinting the extremity or by applying pressure (such as a blood pressure cuff) over the affected joint. Massaging or moving the affected extremity often does not exacerbate the pain. The bends occurs in up to 75% of all decom-
pression injuries. The difficulty in diagnosis is that this often mimics muscle or joint strain.

The chokes are caused by gas embolization that obstructs the pulmonary vasculature. Classic symptoms include shortness of breath, cough, and substernal chest pain, tightness, or burning sensation. The shortness of breath is described as a feeling of suffocation and the individual becomes tachycardic, tachypneic, and hypoxic. An uncontrollable dry cough is common, which is exacerbated by deep inspiration. The chest pain is most frequently appreciated with deep inspiration, increased activity and smoking. There is no radiation of the pain to the neck, arms or abdomen. These symptoms often mimic those of a pulmonary embolism and can lead to cardiovascular collapse.

Cutaneous forms of decompression sickness may cause a variety of skin rashes with or without tingling, numbness, and itching. The release of gas bubbles can also cause subcutaneous emphysema, often involving the neck and other sites. If the neck is involved, the individual may complain of difficulty breathing or swallowing, and may notice a change in phonation.

Other vital organs, including the brain and spinal cord, may be affected by decompression sickness. This may result in headache, visual disturbances (blurred vision, blind spots), sensory disturbance, partial paralysis, confusion, face or jaw pain, seizures, or loss of consciousness.

Emergency treatment for all forms of decompression sickness begins with 100% oxygen and must include rapid descent. Treatment in a hyperbaric chamber will be necessary for severe symptoms that are not resolved with oxygen or descent from altitude. If the patient has recently been diving, hyperbaric treatment should be considered even with apparent resolution of symptoms with oxygen. This is because internal organs may continue to be affected without apparent manifestations.

Scuba divers may be at a high risk for decompression illness if they fly soon after their last dive. A dive to a depth of 30 feet (9 meters) with compressed air will cause the body to absorb twice the normal amount of nitrogen. Subsequently, flying above 8,000 feet (2,438 meters) will be equivalent to a non-diver flying at 40,000 feet (12,192 meters) in an un-pressurized aircraft. Henry's Law will take effect and the nitrogen may escape into the body, resulting in a decompression sickness. The FAA recommends that scuba divers delay flying at least 12 hours when they have been below a 30-foot depth or at least 24 hours after an ascent requiring staging.6

NOISE

Noise and vibration are probably the most annoying and inconvenient factors encountered by air medical personnel. Consistent with many of the stresses of flight, there is individual variation as to tolerance and effect of noise. The longer the exposure is and the more intense the noise, the greater the potential damage.

Noise may be considered any loud, unpleasant, or unwanted sound. Excessive noise within any transport vehicle, air or ground, may interfere with and complicate patient care; it may cause speech interference, and promote hearing loss. Noise generated from aircraft engines, propellers, rotors, ventilation systems, radios, and medical monitoring equipment could make it impossible to auscultate a blood pressure or the lungs. Therefore, it is important for the medical crew to use other means to monitor the patient. Blood pressure can be palpated or monitored through invasive or non-invasive devices. Pulse oximetry provides valuable information about the patient's oxygenation and respiratory status, and CO2 detectors may be helpful when assessing intubated patients. Noise may also impede communications between crew members or between the patient and the crew. Therefore, close observations for a variation in the patient’s vital signs, chest expansion, abdominal distention, level of consciousness, and discomfort may suggest a change in the patient's condition.

During aircraft operation some form of hearing protection should be worn by both the crew and patient. Prolonged and intense exposure to noise may result in temporary or permanent ear damage, deterioration in performance of tasks, discomfort, headaches, fatigue, nausea, visual disturbances, and vertigo. Choices for noise attenuation include earplugs, headsets, and helmets.

VIBRATION

Vibration, which is inherent to all transport vehicles, may interfere with patient assessment and some routine physiological functions. The most common sources of vibration during air medical transport are the power plant of the aircraft and the turbulent air to which the aircraft may be subjected. During helicopter transport, vibration is most severe during transition to a hover or during turbulent weather conditions. In fixed-wing transport, vibration increases during high-speed, low-level flight and during cloud penetration in turbulent weather. In ground ambulances, poor road condition, tight vehicle suspensions, narrow wheelbases, and high centers of gravity predispose these vehicles to rough and turbulent rides, which may be detrimental or excessively painful to patients with spinal cord injury, intracerebral hemorrhage, or orthopedic injuries. Certain patients, such as neonates, may be particularly sensitive to this.

Exposure to moderate vibration results in a slight increase in metabolic rate and is similar to a mild startle
reaction or mild exercise. Low frequency vibration may cause fatigue, shortness of breath, motion sickness, chest pain, or abdominal pain. Low frequency vibration of the eye may also result in blurred vision.

Aircraft vibration may interfere with normal body thermoregulation, causing circulatory vasoconstriction and a decrease in the ability to sweat. Either hot or cold temperatures may aggravate the potential effects of vibration. In the hypothermic patient, vibration may worsen the patient’s condition. In a hyperthermic patient, vibration may delay the body’s cooling ability caused by circulatory vasoconstriction. This could override the body’s compensatory cooling mechanism, impairing the ability to sweat and dissipate heat.

Vibration may interfere with invasive and non-invasive electronic patient monitoring during air medical transport. In-flight vibration has also been shown to cause dysfunction of activity-sensing pacemakers.

Little can be done by pilots or medical crews to eliminate or reduce vibration in the aircraft. This is also true of transport personnel in ground vehicles. However, to minimize the effects of vibration, efforts should be made by the medical crew to avoid or reduce direct contact with the vehicle frame for themselves and the patient. Padding should be placed on any part of the frame that may come in contact with individuals on board. Adequate padding in the form of cushioned seats and stretcher pads, should be utilized. Direct contact with the bulkhead of the aircraft or sides of the ground vehicle should be avoided by placing blankets or other cushions appropriately. Patients and crewmembers should be properly restrained at all times to minimize the effects of vibration. In ground transport vehicles, careful attention should also be made regarding tire pressures, correct loads, appropriate shock absorbers, and overall vehicle maintenance.

**THERMAL CONSIDERATIONS**

During air medical transport both the patient and crew may be exposed to a significant temperature variation, which may result in clinical and operational complications. In fixed-wing transport the principal consideration is for cold temperature. As altitude increases, the ambient temperature decreases an average of 2°C (3.5°F) for every 1,000 feet (305 meters). In helicopter and ground transport, the patient and crew may be exposed to both hot and cold temperature extremes inherent to seasonal changes, geographic considerations, or altitude variation.

Significant deviation from the normal thermal comfort zone may result in clinical and operational significance during air medical transport. Both hyperthermia and hypothermia will create an increased metabolic rate, resulting in an increased oxygen demand and consumption. This additional thermal stress could significantly compromise the hypoxic patient.

Prolonged exposure to temperature extremes could also result in irritability, impaired performance, motion sickness, headache, disorientation, fatigue, discomfort, and a reduced ability to cope with other stresses such as hypoxia. In addition, other stresses such as dehydration, vibration, alcohol and drug intoxication, and certain pre-existing medical conditions could all exaggerate the effects of thermal stress.

The effects of thermal exposure can be magnified by other stresses, including vibration, dehydration, and alcohol and drug intoxication. In addition, climatic temperature variations can create air turbulence, which can negatively impact on the aircraft, crew, and patient.

Many factors can exacerbate or mitigate exposure to temperature variation, such as air circulation, duration of exposure, condition and type of clothing, and physical condition. Whenever possible, the medical crew should take steps to prevent potential complications related to thermal stress. The vehicle cabin should be kept at a comfortable temperature, minimizing exposure to the ambient environmental extremes. Preventative measures against cold exposure and hypothermia should begin with a comfortable cabin temperature to minimize heat loss through radiation and conduction. Layers of clothes or blankets will limit the effects of radiation heat loss and convection. Removing wet clothes or large moist dressings will prevent excessive heat loss through evaporation and conduction.

Prolonged exposure to high temperatures may require increased oral or intravenous fluids to prevent dehydration. The use of increased ventilation, cool water mist, or moist dressings may be of benefit until the patient and crew can enter a cooler environment.

No matter which medical transport vehicle, it is recommended that the medical crew always be "dressed for the weather." In the summer, it may be appropriate for the medical crew to undertake a transport wearing shorts and a hospital lab coat. However, as the temperatures get colder, this would not be adequate, as the crew should be prepared for prolonged "unexpected" exposures to the elements. This may be due to an accident, vehicle breakdown, remote locations, and changes in environmental controls. In the winter, appropriate attire includes a winter coat, gloves, hat, and layered clothing.

**GRAVITATIONAL FORCES**

The impact and importance of gravitational force (G-forces) as a stressor during air medical transport are often discussed and debated. During routine flight operations, G-forces will not significantly impact the patient.
or the crew. However, an understanding of gravitational forces will explain how such forces may be relevant to crew and patient positioning within the aircraft, as well as to safety and accident survival.

The force a person exerts when seated is in direct response to the gravitational force imposed on the body, is equal to weight, and is known as 1 “G.” Even though gravitational forces (G-forces) are not a significant factor with most aircraft used for air-medical transport, G-forces are applied to the body on ascent and descent and during a change in speed or direction. Acceleration is the rate of change in velocity and is measured in Gs.

In theory, the effect of G-forces may be enhanced or minimized by patient or crew positioning within the aircraft. During deceleration (landing), an unrestrained or improperly restrained person in a forward-facing seat may be injured or ejected from their seat. In contrast, a rear-facing seat may provide better restraint during crash deceleration.

For patients with cardiac disease, it may be possible to improve myocardial perfusion during acceleration by positioning the patient with their head toward the back (aft) portion of the aircraft. As negative G-forces are increased, pooling of blood occurs in the upper part of the body. In head injury victims or fluid overloaded patients, it may be advantageous to augment positive G-forces, which would pool blood in the lower extremities. This is accomplished by positioning the patient with their head toward the front (fore) portion of the aircraft. In head injured patient, this may reduce the risk of a transient increase in intracranial pressure during takeoff.

Humidity / Dehydration

As altitude increases and the air cools, the amount of moisture in the air drops significantly. Therefore, a pressurized aircraft that draws its fresh air from the outside dry atmosphere will result in a pressurized cabin with an extremely low humidity level. In addition, inherently dry medical oxygen will further predispose the patient to dehydration.

During prolonged high altitude transports, both the patient and crew will be exposed to very low humidity. Crewmembers and patients may develop signs of dehydration, which could include dry mucous membranes, dry mouth, chapped lips, sore throat, hoarseness, dry or scratchy eyes, and thirst.

The decrease in humidity is particularly important as it relates to patient airway secretions. Dried airway secretions can lead to airway obstruction, collapse, less efficient gas exchange, and hypoxemia. In addition, respiratory secretions may become thick, contributing to hypoxia. Dehydration can also stimulate the hypothalamus, resulting in an increased metabolic rate and increased oxygen requirements.

Steps must be taken to avoid dehydration during air medical transport. In-flight oxygen should be humidified for all patients and fluid intake (oral or IV) must be appropriately monitored, especially during long transports. Similarly, dehydration prior to transport may be exacerbated by altitude induced circulatory changes.

THIRD SPACING

Third spacing, the loss of fluids from the intravascular spaces into the extravascular tissues, may develop or be exacerbated during long-distance or high-altitude air medical transport. There are numerous factors that work together to maintain the integrity of the cell wall and any alteration may result in the leakage of fluid. Pressure surrounding the vessel walls helps to preserve the fluid within the vessels and a decreasing ambient pressure may cause leakage of the fluid from the intravascular space into the tissues. Increased intravascular pressures or increased permeability of the cell walls may also account for fluid loss.

Patients with cardiac or nephrotic disease, who have pre-existing fluid leakage, may be at risk for increased third spacing due to an increasing altitude and decreases in barometric pressure. Burn patients are also at risk for third spacing as well as increased insensible losses.

Signs and symptoms that may occur include edema, dehydration, increased heart rate, and a decreased blood pressure. The potential onset and complications of third spacing may also be aggravated by other stresses of flight, including temperature extremes, vibration, and G-forces.

FATIGUE

While fatigue is considered to be one of the stresses of transport, it may also be considered an end-product of the other contributing factors that make up the stresses of flight and the self-imposed stresses. Hypoxia, gravitational forces, barometric changes, and dehydration all contribute to fatigue that may compromise both the crew and patient. By understanding the elements that cause and contribute to fatigue, the medical crewmember may be able to mitigate the impact of this stressor.

Fatigue is a state or condition that follows a period of excessive mental or physical activity or inactivity. The emotional and physical stress of prolonged patient care in the transport environment may be very challenging and may result in fatigue. It is important for the medical crewmember to minimize the factors that can contribute to fatigue, especially the self-imposed stresses, which should be within their direct control. Fatigue will be discussed in more detail in the next section of this chapter.
SELF-IMPOSED STRESS

Air and ground medical transport requires that each member of the “team” function at peak performance to assure the highest level of aviation safety and patient safety. For this reason, the importance of the self-imposed stresses cannot be understated. For many crewmembers, self-imposed stresses may play an even more important role and a more frequent factor than the various stresses of transport. Self-imposed stresses can adversely affect anyone during air or ground transport and can impact physiological performance and response. Therefore, having a clear understanding of these stresses is important for optimal safety and patient care. The acronym “DEATH” is often used to remember the components: Drugs, Exhaustion (fatigue), Alcohol, Tobacco and Hypoglycemia (diet/dehydration). However, another way to approach the all-important self-imposed stresses is by way of a personal evaluation.

Pilots and crewmembers are familiar with the routine aircraft pre-flight at the beginning of a shift and a specified pre-flight checklist prior to departure to validate the mechanical condition of the aircraft and readiness for flight. Aircraft systems failures, however, are less frequent than various pilot (or crew) impairments that may contribute to accidents and incidents. The FAA Advisory Circular on Aeronautical Decision Making suggests that pilots pre-flight themselves as carefully as they pre-flight their aircraft in order to assess their physical and emotional readiness to fly. Each member of the medical crew should undertake the same process as a way to evaluate his or her self-imposed stresses and to determine if “I’m safe.” The letters in “I’m safe” correspond to: Illness, Medication, Stress, Alcohol, Fatigue, and Eating. This simple personal checklist (Table 39-6) contains all of the elements common to impaired performance and can easily be committed to memory by each crewmember.

<table>
<thead>
<tr>
<th>Illness</th>
<th>Do I have any symptoms?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medication</td>
<td>Am I taking prescription or over-the-counter medications that could impair my performance?</td>
</tr>
<tr>
<td>Stress</td>
<td>Am I experiencing any signs and symptoms of stress? Do I feel hurried or stressed by any work, home or personal situations? Are there any specifics about this transport that may result in a stressful situation?</td>
</tr>
<tr>
<td>Alcohol</td>
<td>Have I had any alcohol within the past 8 hours? Within 24 hours?</td>
</tr>
<tr>
<td>Fatigue</td>
<td>Am I adequately rested?</td>
</tr>
<tr>
<td>Eating</td>
<td>Have I eaten enough to keep adequately nourished and hydrated during the entire flight?</td>
</tr>
</tbody>
</table>

Table 39-6: “I’m Safe” Checklist

ILLNESS

An acute or chronic illness can easily impair a pilot or crewmember. Even minor illnesses can seriously degrade performance. In December 2000, a medical helicopter crashed after the pilot became incapacitated from nausea and collapsed on the cyclic during the final approach to landing.

An illness with fever, headache, malaise, pain or other distracting symptoms gets in the way of judgment, memory, alertness, and one’s ability to concentrate. In addition, be wary of any illness that requires medicine to make you feel better. If an illness is serious enough to require medication, it may also be serious enough to consider not flying (or doing ground transports). Remember also that, during a flight, any URI, allergies, sinus problems, sore throat, ear infection, or GI distress may be exacerbated with the changes in atmospheric pressures and altitude.

The best rule is not to fly when ill, but this is not always possible. As part of the “I’m safe” checklist, each crewmember should ask, “Do I have any symptoms?”

MEDICATION

At times, it may not be the medical condition, but the prescription or non-prescription medication that someone is taking that may interfere with performance, perception, decision-making, and motor skills. Crewmembers must be aware of predictable side effects, overdose problems, allergic reactions, and possible synergistic effects of medication they may be taking.

Prescription medications often have the potential for more serious side effects than over-the-counter medications. Strong pain relievers, tranquilizers, and sedatives can impair judgment, memory, alertness, coordination, and vision. Other drugs, such as antihistamines, muscle relaxants, blood pressure medication, and agents to control diarrhea and motion sickness can also impair the same critical functions. Antihistamines often cause drowsiness while decongestants can cause stimulation or nervousness. Caffeine (contained in coffee, tea, soft drinks, and chocolate) is also a strong stimulant to many individuals. When mixed together with decongestants, caffeine may cause an individual to become increasingly “hyper.” Some cough syrups contain a decongestant or antihistamine. Others use alcohol as a base for their ingredients. A particular concern in the air medical environment is that any medication that depresses the nervous system, such as a sedative, tranquilizer, or antihistamine, can make a pilot or crewmember more susceptible to hypoxia.
While there are known potential adverse effects of medications, every individual may respond differently to the same medication. The best strategy is to read and follow the warnings on the label. If a label warns of side effects, consider waiting twice the recommended interval to be certain that you are “safe.” An obvious consideration is to avoid taking any new medication while on duty or before a transport.

FAA regulations prohibit pilots from performing crewmember duties while using any medication that may adversely affect their faculties and impact safety. Considering the critical role the medical crew plays with regard to overall aviation and patient safety, common sense would dictate the same rational approach for the entire transport team.

STRESS

The effects of stress are often difficult to recognize. It is this inability to recognize stress that may be hazardous in aviation and during transport. Failure to manage stress often leads to eroded judgment, errors in decision making, decreased work performance, inattentiveness, degraded communication skills, preoccupation, and complacency. A pilot suffering from stress may forget or skip procedural steps, accept lower performance standards, and exhibit a tendency toward spatial disorientation and misperceptions. These misperceptions may result in misreading maps, charts and checklists, misjudgment of distance and altitude, and loss of time perception. In a study of more than 700 naval aviators who had been involved in major aircraft mishaps over a four-year period, it was determined that those pilots who exhibited the symptoms of inadequate coping mechanisms for dealing with stress were more likely to be involved in an aircraft mishap.

Other common signs and symptoms of stress include anxiety, irritability, impulsiveness, aggressiveness, emotional or physical isolation, problems concentrating, and difficulty remembering important things. An individual may also experience diarrhea, indigestion, frequent urination, headaches, grinding teeth, cold sweats, increased smoking or over-eating, and alcohol or drug use or abuse.

Everyone is familiar with stress. It’s part of life as we adjust to our continually changing environment at home, on the job and in nearly every aspect of our lives. We experience it in varying forms and degrees every day and may react to stress differently. Some forms of stress are normal, essential and can be beneficial. It is only when the stress becomes too great, affecting our physical or mental functioning, that it becomes a problem. In small doses, stressors can be challenging and actually helpful – as a positive influence pushing us to reach beyond usual limits. They help give us increased energy and alertness, even helping to keep us focused on the problem at hand. This type of stress is good. People may refer to the experience of this type of stress as feeling “pumped” or “wired.”

Top stress producers include emotionally upsetting events, such as an argument, the death of a family member, a separation or divorce, the loss of a job, or financial catastrophe. However, in transport medicine, daily events may result in varying stressors to the pilot and crew. This also includes the otherwise “routine” transport. Encountering bad weather, night operations, scene transports, performing an instrument approach in poor conditions, flying in high density traffic area, flying in a back-up aircraft, and flying in unfamiliar areas are all examples of potential stressors. Equipment malfunctions, the critical nature of the patient, and interpersonal conflicts with other crewmembers may also be areas of stress for both the pilot and medical crew. The other elements of “I’m safe” (illness, medication, alcohol, fatigue, and eating), if present, will also play a significant role in individual stress.

As the level of pressure gets too great, either from too much stress or too many stressors, our ability to cope in a positive way is impaired or overwhelmed. Often, people describe themselves as being “stressed out,” “burned out,” or “at wit’s end.” At this point, it is important to find positive and productive ways to deal with the stress and, more important, to address the person or situation that is causing the stress. Otherwise, stress can lead to physical, emotional, and behavioral disorders that can readily compromise an individual’s health and work performance.

Each individual has a different level of pressure and anxiety that can be handled without a bad outcome. Every crewmember should be aware of the varying stressors and their own tolerance to stressful situations. The best treatment for undue stress is prevention. It is better to avoid getting into situations that are likely to overwhelm the crew’s ability to cope. This is not always possible since stressors often come from outside sources that may be beyond an individual’s control.

There are many ways to deal with personal stress. The most effective strategy is to identify the source of stress and then evaluate what resources may be available to limit the stress or lessen the impact of the stress. Possible solutions should be explored and one should take the appropriate action. Finally, it is essential to evaluate the outcome, make corrections or changes as needed and then try again.

ALCOHOL

There are serious hazards of combining alcohol and flying. Alcohol is a depressant, hypnotic, and additive
Principles and Direction of Air Medical Transport

drug that in any quantity will have adverse effects on one's flying ability. As little as one ounce of liquor, one bottle of beer, or four ounces of wine can impair a pilot's skills. The alcohol consumed in these drinks can be detected in the breath and blood for at least three hours. In addition, the effects of alcohol ingestion have a tendency to be exacerbated "at altitude." One drink at 10,000 feet (3,048 meters) is equivalent to 2-3 drinks ingested at sea level.

Federal Aviation Regulation (FAR) 91.17 regulates the use of alcohol and drugs by pilots. Among other provisions, this regulation states that no person may act or attempt to act as a crewmember of an aircraft within 8 hours after the consumption of any alcoholic beverage; while under the influence of alcohol; with a blood alcohol content of 0.04% or greater; or while using any drug that adversely affects the person's faculties in any way contrary to safety.

Alcohol blocks impulses from the brain and decreases the ability of the brain to use oxygen. The majority of adverse effects are to the brain, eyes, and middle ear—all crucial organs in aviation. It can slow reaction time, impair judgment, impair memory, impair vision, impair hearing, increase fatigue, and can make a pilot much more susceptible to spatial disorientation and hypoxia.

Individual metabolism of alcohol may vary, and a pilot may still be under the influence much longer than eight hours after drinking. In addition, after the body completely metabolizes a moderate amount of alcohol, an individual can still be impaired for many hours by a hangover. An excellent rule to follow is to allow at least 12 to 24 hours between "bottle and throttle," depending on how much alcohol one drinks. In some cases, the effects of a hangover may last even longer, up to 48-72 hours after drinking alcohol, and may be just as dangerous as intoxication itself. Symptoms include impaired judgment, fatigue, irritability, headache, dizziness, dry mouth, stuffy nose, upset stomach, and sensitivity to light.

These same concerns and considerations regarding alcohol should also apply to the medical crew. In addition to compromising the medical care provided, it is also a concern with regard to the important role the medical crew plays to assure the safety of transport.

FATIGUE

Fatigue is one of the most treacherous hazards to flight safety. Pilots and crewmembers might not notice its presence until a serious error occurs. All transport team members, including medical personnel, ambulance drivers and aircraft pilots, must avoid exhaustion or fatigue to prevent errors in judgment, poor attention span, and decreased work capacity and performance.

There are two basic categories of fatigue. The first to develop is acute fatigue and it is a normal result of day-to-day activities. It is the tiredness you feel after periods of significant mental and physical strain, including strenuous activity, immobility, heavy mental workload, strong emotional pressure, monotony, and sleep deprivation. Acute fatigue is accompanied by a feeling of being tired, reduced alertness, a desire for rest, inattention, distraction, errors in timing, need for greater stimuli, neglect of secondary tasks, loss of accuracy, coordination and control, and unawareness of error accumulation.

Acute fatigue is usually remediated by adequate sleep. In addition, exercising regularly and eating properly will also help resolve this hazard. While all of us may be susceptible to acute fatigue, flight crews on rotating shifts or subject to working in changing time zones are particularly susceptible. Considerations for alterations in sleep patterns should be made to lessen the impact of fatigue that may further complicate a transport.

Chronic fatigue is potentially more serious than acute fatigue and generally represents a self-imposed stress rather than a stress of flight. Chronic fatigue is usually a result of not having enough time to recover completely between episodes of acute fatigue. Presenting signs and symptoms include: physical and mental tiredness, insomnia, depression, irritability, poor judgment, loss of appetite, weight loss, and slowed reaction time. In some cases, the underlying cause may be related to personal factors (family, money, etc.). Causative agents for both acute and chronic fatigue must be addressed accordingly so as not to compromise patient care or jeopardize personal or transport safety.

Concerns, controversy and research regarding fatigue in health care providers have received a great deal of attention in recent years. This has also been a concern regarding pilots of medical helicopters. Since 1985, the Federal Aviation Administration (FAA) has regulated pilots' maximum duty hours. The FAA had become concerned that fatigue was a contributing factor in many helicopter EMS accidents. Federal aviation regulations were changed to include duty time limitations (14 hours on in any 24 hour period), maximum flight hours (8 hours of flying in a 24-hour period) and required rest before a next shift (10 hours).

Similarly, as of July 2003, the work rules of the Accreditation Council for Graduate Medical Education (ACGME) were established to limit resident physicians. Residents are now limited to a maximum of 80 hours per week and 30 hours on duty at a time. Residents are
required to have a minimum of 10 hours off between shifts and one day off in seven.

The National Transportation Safety Board (NTSB) has identified fatigue as causal or contributory in accidents in every mode of transportation. Since 1972, they have issued nearly 80 fatigue-related safety recommendations. In 1998, the Chairman of the NTSB testified before the Committee on Transportation and Infrastructure, House of Representatives, regarding human fatigue in transportation. The Chairman stated, "Human fatigue in transportation operations is probably the most widespread safety issue in the transportation industry." In a consensus document published in 2000, scientists estimated that 15-20% of all transportation accidents are fatigue related and that official statistics generally underestimate the role of fatigue. In addition, they stated that the contribution of fatigue to accidents surpasses that of alcohol and drugs.

Despite the findings and recommendations of the FAA, ACGME and numerous research studies, the air medical transport community remains divided regarding duty time and fatigue. More and more programs have their medical crews working 24-hour shifts, with varying policies, if any, to prevent fatigue. Unfortunately, there are no other uniformly accepted work rules to govern transport teams. Another concern outside of crew scheduling is that in addition to 24-hour shifts, some team members may work several jobs or shifts and often back to back.

In 2004, the Air Medical Safety Advisory Council (AMSAC) developed a "Recommended Practice" regarding medical crew rest guidelines. They recommend that on-site medical crew shifts be scheduled in much the same manner as the pilots, limiting the duty day to a maximum of fourteen hours with at least ten hours of uninterrupted rest between shifts. It is not recommended that any shifts be scheduled for any period to exceed 14 hours. If shifts are scheduled to exceed 14 hours, AMSAC suggests that six requirements be met, as identified in Table 39-7.

Table 39-7: AMSAC Recommendations for Scheduled Shifts That Exceed 14 Hours

<table>
<thead>
<tr>
<th>AMSAC Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The program can reasonably expect that the medical crewmembers will not be required to routinely perform any duties beyond those required for readiness of the aircraft, equipment, supplies, and/or administrative duties directly associated with the performance of their flight duties.</td>
</tr>
<tr>
<td>2. Those medical crewmembers are provided with access to and permission to rest after duty.</td>
</tr>
<tr>
<td>3. Medical crewmembers must have at least ten hours of uninterrupted rest prior to any scheduled shift. This is intended to preclude back-to-back shifts with other employment or significant fatigue-causing activity prior to a shift.</td>
</tr>
<tr>
<td>4. A medical crewmember must have the right to call &quot;time out&quot; from flight duties if the crewmember (or fellow flight team member) determines that he or she is unfit or feels unsafe to continue duty, no matter what the shift length. There should be no adverse personnel action or undue pressure to continue in this circumstance.</td>
</tr>
<tr>
<td>5. Management periodically reviews flight volume, frequency and mission duration in determining the efficacy of scheduled shifts greater than fourteen hours.</td>
</tr>
<tr>
<td>6. Medical crewmembers should not accept flights or shifts that they know will extend beyond twenty-four hours unless approved by a manager who can verify that crewmembers have had at least ten consecutive hours of uninterrupted rest in the previous twenty-four hours.</td>
</tr>
</tbody>
</table>

EATING

A properly balanced diet and adequate hydration represent the final self-imposed stress and element to insure that "I'm Safe." An inadequate diet, hypoglycemia, or dehydration can result in nausea, headache, dizziness, weakness, errors in judgment, irritability, nervousness, trembling and loss of consciousness. Precautions should be taken to avoid the development of hypoglycemia or dehydration.
SUMMARY

Medical transport represents a significant challenge for personnel providing medical care to the critically ill or injured. With an in-depth knowledge of transport physiology and the stresses of flight/transport, the crew will be capable of providing optimal patient care. A well-trained crew will be able to anticipate potential complications and will be able to minimize their effects through suitable intervention prior to and during air or ground medical transport.

Hypoxia represents the greatest potential hazard that may be encountered during high altitude air medical transport. A thorough knowledge of hypoxia, its causes, symptoms and the correct use of available intervention are paramount.

The effects of barometric pressure changes on air in an enclosed space may complicate patient care and cause pain or discomfort for both the crew and patient. Gas expansion in medical equipment and body cavities should be anticipated and the appropriate precautions taken.

The stresses of transport and self-imposed stresses may further complicate patient care during air or ground medical transport. In addition, these stresses may result in impaired work performance of the crew. It is especially important for the medical crew to minimize the effect of self-imposed stresses and to “pre-flight themselves” with an “I’m Safe” checklist everyday and every transport.

SUGGESTED READING

CONSIDERATIONS IN AIR MEDICAL TRANSPORT OF THE CRITICALLY ILL PATIENT

INTRODUCTION

Critically ill and injured patient care is optimized when delivered in facilities offering highly skilled personnel and advanced diagnostic and therapeutic technology. For some high-acuity patients, outcomes are improved by early attention from appropriately qualified and experienced providers with access to advanced medical modalities. Since the experience and technology pertinent to the development of special expertise in critical care tends to be concentrated in large centers, specialization and regionalization have for years been common for an ever-increasing variety of patient types (e.g., trauma, burn, cardiac, neonates).1,2

Regionalization of care inevitably translates into a need to move patients between hospitals. The chances of smooth and successful execution of these interfacility critical care transports are maximized by a well-coordinated effort involving experienced out-of-hospital care providers. Against the benefits of interfacility transport should be weighed the potential risks of transporting critically ill patients—risks that are low, yet difficult to precisely estimate based upon available evidence.3 Examples of risks entailed in patient transport include oxygenation and ventilation abnormalities, detrimental changes in blood pressure, and cardiopulmonary arrest.4,5

In the final analysis, the decision to transport a patient must be based on the belief that the risks of transport are outweighed by the potential benefits patients will accrue at the receiving facility. Transport programs can favorably influence the risk/benefit equation by reducing transport risks; this is achieved through a combination of training, cooperation, clinical acumen, and attention to detail.

PROGRAM MISSION

The mission statement describes the reason for a transport program’s existence and should reflect the fact that a program’s goal is to further the interests of the served community. Clarity of the mission statement enables the transport program to define goals and to determine areas in which to focus resources. If the program decides its primary mission includes interfacility transports of the critically ill patient, certain considerations must be addressed.

Formulation of a transport program’s mission statement should take into account regional practices for interfacility transport. The need for a transport program’s mission to address interfacility critical care transport is increasingly likely since regionalization of care is frequently encountered for a variety of patient types (e.g., trauma, burns, neonatal illness, stroke, acute coronary syndromes).5 It is likely that resource-intensive interventions and procedures will be increasingly concentrated due to economic and other pressures (e.g., establishment of corporate hospital networks). Overall, a variety of factors are contributing to a growing need for interfacility transport capabilities to redistribute patients within a given hospital network.

Regardless of the impetus for a given pattern of interfacility transports, critical care transport programs can play an important role in establishing, monitoring and supporting regional systems of care. For example, the critical care transport program can work with hospitals to reduce transport-related inefficiencies such as multiple interfacility transports for the same patient, which may occur if the first transport is to an institution incapable of meeting the patient’s needs. The program’s mission should also include a goal to foster collaboration between referring and receiving institutions in an ongoing effort to achieve the best possible integrated care systems for the critically ill and injured.

PROGRAM PHILOSOPHY

In most areas, air medical programs were initiated to transport trauma patients. In fact, “golden hour” trauma considerations were integral to the idea that speed was the major mechanism through which air transport improved outcome for injured patients. While speed obviously contributes, in many instances, to improved outcome, there is clearly more to the issue. Even the seminal work by Bax6 noted longer prehospital times
for the air transported group and the overall body of trauma outcomes literature confirms that there is more to the story than logistics.\(^1\)

The added benefit beyond time savings seems to lie in the ability of the transport crews to provide high quality critical care during transport, as well as essential stabilization prior to transport. Some programs, as well as program administrators who are accustomed to quick turnaround times and short bedside times, may have difficulty accepting the prolonged ground times required for stabilization of some critically ill patients. Air and ground programs that routinely transport critically ill patients must remember that the overall goal is improved patient outcome—not necessarily speed. In many cases, optimizing pre-transport stabilization is likely to improve outcome. Thus, extended transport times may be an expected component of critically ill patient transfers. This is not to minimize the importance of speed when dealing with time-critical conditions that need definitive intervention as soon as possible. For these patients, extended ground times might be detrimental.

The topics of crew configuration and medical crew training are addressed in detail in their own chapters. However, a few aspects specifically pertinent to critical care transport will be addressed here.

**CREW COMPOSITION**

The composition of air and ground transport crews can vary. The majority of programs utilize non-physician critical care transport teams with the most common crew configuration being nurse/paramedic. However, the paper credentials of crews providing critical care transport may be less important than crewmembers' adherence to a rigorous curriculum of initial and ongoing training. In fact, though methodologically rigorous outcome studies focusing on crew composition are rare, the extant literature suggests that well-trained non-physician crew are able to effectively transport critically ill and injured adults and children.\(^1\)\(^2\)\(^3\)

Regardless of the transport team's configuration, flexibility is essential when it comes to critical care transport. The team members' areas of clinical expertise should be complementary. A program should strive for the ability to alter the critical care crew (or add additional personnel) based on the needs of a specific patient (e.g., a sick neonate or a patient on an intra-aortic balloon pump). Depending on clinical and logistical circumstances, additional personnel who might be added could include a physician, second nurse or respiratory therapist.

One common arena in which additional personnel are used is the transport of critically ill neonates; a critical care transport team may have extensive transport experience, but limited experience in the care of neonates. The program may thus require a neonatologist or neonatal nurse to accompany the transport crew on these specialty transports. If the critically ill neonate requires nitric oxide during transport, a respiratory therapist may need to be added to the mix.

An additional advantage in maintaining flexibility in crew composition is the ability to transfer a broader variety of patients with decreased operating costs. Development of a roster of specialty personnel allows maintenance of both stable transport crew composition and selection of additional personnel based on specific patient needs. This fosters a mutually beneficial relationship wherein specialty personnel are utilized for transport crew education and transport crew are utilized for transport environment training.

**EXPERIENCE, TRAINING AND EDUCATION**

To meet the unique crew needs of a critical care transport program, transport nurses should be recruited from a pool of applicants with experience with patient populations that mirror those patients transported. Paramedics, who tend to be hired for particular expertise in scene trauma management, must expand their knowledge bases with critical care medicine exposure from both didactics and spending time in the ICU setting during clinical rotations. If respiratory therapists are part of the crew, they too must have adequate ICU exposure. Ongoing continuing education, formalized in a program's plan of clinical rotations and didactics, should reflect the needs of a given transport program to insure its educational content is appropriate for the patient population that will be transported.

The road to successful personnel training for critical care transport begins with identifying highly motivated individuals with diverse backgrounds, who have at least some experience in the care of critically ill and injured patients. These persons should optimally have demonstrated aptitude in the special skills and technology management challenges entailed in caring for the ICU patient population. The well-rounded training of a critical care transport crew may start—but certainly does not end—with maintenance of certification in courses such as ACLS (Advanced Cardiac Life Support), ATLS (Advanced Trauma Life Support), and PALS (Pediatric Advanced Life Support). Transport crews providing neonatal transport have found benefit to maintenance of currency in the Neonatal Resuscitation Program (NRP).

The Fundamentals of Critical Care Support (FCCS) course is a newer addition to the menu of educational opportunities. In the experience of some transport programs it is a useful means to increase awareness of critical care issues such as hemodynamic monitoring,
Principles and Direction of Air Medical Transport

acid-base pathophysiology, electrolyte balance, and mechanical ventilation. The FCCS is especially useful for transport personnel whose background does not include extensive experience in critical care units.

The educational endeavors of a transport program do not end with didactics and certification courses. These more individual-focused efforts should be complemented with team-building exercises and simulation training, since the latter approaches are essential components to the development of high performance transport crews. These types of educational and “practice” opportunities afford transport crew members a chance to learn how to work together and problem-solve in a risk-free setting.

Traditionally, personnel attracted to air medical transport enjoy quick, dramatic patient interventions. However, the critically ill patient requires skills which at first blush may seem prosaic; in critical care transport, patient care is optimized by meticulous attention to detail and prospective planning to ensure smooth transport. The transport crew must be facile at making the transition – perhaps on consecutive missions – from the skills and mindset required for scene trauma response, to those needed for management of the patient in cardiogenic shock. For new crew members, especially those whose primary clinical experience has been with trauma patients, the transition may be challenging. Even those crew members with extensive experience in critical care medicine (e.g., ICU nurses) find that continuing education is vital to stay abreast of new developments.

THE MOBILE ICU

The aircraft, as well as the critical care ground ambulance, can be perceived as an extension of the ICU and should provide the same level of care and expertise during transport. This goes for both helicopter and fixed-wing vehicles, since even the most critically ill patients have been successfully transported (some for long distances) via airplane.4 Since they strive to provide a transport-setting ICU, critical care transport teams must be capable of managing ICU-level sophisticated life support equipment: invasive hemodynamic monitoring, hemodynamic waveform interpretation, manipulation of mechanical ventilators, initiation and titration of ICU pharmacology, and use of intra-aortic balloon pumps and cardiac assist devices.

MEDICAL CONTROL

Critical care transport programs whose transport crews consist of nurses, paramedics, respiratory therapists, or other allied health care providers deliver care under both direct (on-line) and indirect (offline) medical oversight. Most transport programs utilize emergency department physicians for on-line medical direction. Emergency medicine and other non-ICU physicians must have rapid consultative access to ICU physicians knowledgeable in transport medicine. The medical director of the transport program must insure that physicians utilized for medical control can impart appropriate advice and direction for the critical ICU patient. Though numbers vary, in some flight programs 50% or more missions will be interfacility transports of critically ill patients. In addition to being available for assistance with direct medical oversight, intensivists with expertise in the transport environment should be involved with indirect oversight procedures such as case reviews, policy and procedure development and quality management. Services that transport critically ill adult, pediatric, and neonatal patients should have available consultants with expertise in each discipline.

COMMUNICATIONS

The involvement of the communications specialist is integral to a program’s successful execution of efficient critical care transports. Communications specialists are responsible for triaging and coordinating logistics of transport requests. Judgment must be exercised by the communications specialist. Whereas in general, a request for transport should prompt immediate dispatch of a vehicle, a request for critical care transport may trigger requirements for additional information and/or mobilization of additional resources before a vehicle is sent. The communications specialist is trained to gather information so that they can expedite dispatch of an appropriate vehicle, with appropriate resources and personnel. After vehicle dispatch, the communications specialist continues to contribute to the safe and efficient execution of transport, by maintaining open lines of information exchange between referring, transporting, and receiving personnel.

EQUIPMENT CONSIDERATIONS

EQUIPMENT SELECTION

Equipment selection for critical care transport should meet all general transport guidelines. General recommendations state that transport equipment be portable, lightweight, durable, self-contained, and able to withstand mechanical, thermal and electrical stress. Furthermore, transport equipment should be easily
cleaned and maintained, and must not interfere with aircraft navigation or communications systems.

Space considerations preclude detailed discussion of particulars of the myriad types of equipment that may be used or encountered by a critical care transport team. Depending on the patient profile encountered by a program, crews may need to be familiar with different types of ventilators, monitors, infusion pumps, ventilator assist devices, nitric oxide delivery systems, intra-aortic balloon pumps, and pacers/defibrillators. One important fact to keep in mind is that the smooth functioning of a piece of equipment in the ICU — or even in a patient's home — does not guarantee a seamless transition to the transport setting. As in many other aspects of transport medicine, the best means for handling equipment issues is to be thoroughly familiar with how equipment works, and how to troubleshoot problems arising during transport. For example, in a region in which patients are discharged with home ventilator assist devices, the critical care transport crew would benefit from having an "in-service" from the hospital-based cardiology service responsible for these patients. This kind of educational time, spent on learning the ins and outs of specific equipment, may be time well spent if a crew expects to encounter patients on infrequently-seen devices.

Adult extracorporeal membrane oxygenation (ECMO) represents a newer advancement in critical care and interfacility transfers of these patients may be part of the future. Ventricular assist devices have also been used during helicopter transport, as well as during long-distance fixed-wing transport.

MONITORING

One of the aims of critical care crews is to maintain monitoring initiated prior to transport. Since referring institutions may have limited resources, and those resources available at referring hospitals may be inappropriate for the transport environment, transport crews should bring with them equipment necessary for ventilatory and invasive hemodynamic monitoring. Depending on a particular transport's logistics and clinical circumstances, some hemodynamic monitoring used in the ICU setting may not be practical during transport. In these circumstances, the crew's responsibilities will lie with securing monitoring equipment so that it can be used at the receiving institution. In general, though, the goal of the transport crew will be to maintain the highest level of pretransport monitoring during the interfacility care of the patient. As with other topics encountered in this chapter, the discussion relevance is not limited to ground or helicopter vehicles; use of complex monitoring and associated critical care technology has been well-described for fixed-wing operations.

Intratransport monitoring that medical crews could encounter ranges from the frequently encountered (e.g., arterial line transduction) to the somewhat novel (e.g., bladder probe monitoring of intra-abdominal pressure), to the still-experimental (bipolar index processed EEG equipment). The common thread is that the critical care transport crew should be ready to handle a variety of systems that may be in use in their service areas. Some notes about particular types of monitoring follow, to serve as examples of the application of transport principles to critical care monitoring.

Intracranial Pressure Monitoring

For intracranial pressure monitoring, the transport crew should insure that the pressure system remains closed to the patient, and opened only in a controlled environment for periodic readings. In patients with ventriculostomies, the crew should assure that the ventriculostomy bag is level (the pretransport level should be maintained) for the duration of the transport. Adjustments should be made only on direction of a physician, and the drainage bag should be leveled at the patient's tragus.

Pulmonary Arterial Catheters

For patients with pulmonary arterial (PA) catheters, two issues of particular import to the transport crew are (1) assurance that the catheter is not wedged during transport, and (2) vigilance for catheter dislodgment. Patients should not be transported with a permanent wedge tracing; rather, the catheter's balloon should be deflated and the PA line should be withdrawn until an acceptable tracing is documented. Transport crew should be on the lookout for signs of PA catheter dislodgment (e.g., ventricular dysrhythmias, dampened waveforms). If there is concern for catheter malpositioning, crews should have the patient change position, breathe deeply, or cough. If these maneuvers don't work, the crew should consider withdrawing the PA catheter line such that the tip is in the right atrium (20-25cm depth depending on insertion site).

Ventricular Assist Device

One hemodynamic intervention that requires particularly close monitoring during transport is the ventricular assist device (VAD). Careful attention to detail is necessary for safe and effective transport of VAD patients, since the devices are characterized by unique monitoring and associated intervention issues. For example, cardiac rhythm abnormalities in the VAD patient are of vital import for crews to monitor, since some aspects of dysrhythmia care differ in VAD patients.
(e.g., anticoagulation, provision of hand-pump cardiac output support, need to disconnect from power sources prior to defibrillation).

**Laboratory Parameters**

Critical care transport programs have also reported monitoring of laboratory parameters. Using a portable point-of-care device, air medical critical care transport crews have been able to report streamlined stabilization and cost-beneficial care for pediatric patients. On a related note, physiologic monitoring of ventilator-related parameters comprises an important part of intratransport care; this is addressed in the next section.

**MECHANICAL VENTILATION**

Use of mechanical ventilators during transport of the critically ill patients is highly recommended. Many ventilator-dependent patients require significant support to maintain adequate oxygenation and ventilation. For example, preservation of tissue oxygenation and protection of the lungs in the patient with adult respiratory distress syndrome (ARDS) may require up titration of FIO2, addition of positive end-expiratory pressure (PEEP), and/or employment of controlled pressure modes. Traditional bag-valve-endotracheal ventilation may not adequately maintain the patient's oxygenation. Manual ventilation may also result in hypo- or (more commonly) hyperventilation, with attendant physiologic deterioration.

As compared with manual ventilation, use of mechanical ventilators reduces variability in tidal volume, respiratory frequency and PEEP. Transitioning to mechanical ventilation also frees a crewmember from the potentially tiring task of providing manual breaths. In fact, for long transports, manual ventilation is not practical since it incurs such risk of unpredictable, inconsistent ventilatory support.

The patient should be transitioned to the transport ventilator in the sending hospital, with subsequent assessment of stability prior to any movement to the transport vehicle. This practice inherently prolongs pretransport time, but is nonetheless invaluable as it allows the transport crew to observe a patient's tolerance to the ventilator transition. Since critical care patients' ventilator transitions may not always go smoothly, it is preferable to have the opportunity to troubleshoot problems with the “safety net” of ready availability of the referring hospital ventilator.

When selecting a transport ventilator, certain criteria should be considered. Depending on the transport population profile of the critical care transport program, the ventilator should be able to provide support to both adult and pediatric patients. This requires high variability in tidal volume delivery and frequency of ventilation, as well as the capacity to control ventilation pressures. The mechanical ventilator should be able to provide ventilation in both volume- and pressure-control modes.

When utilized in a volume-control mode, the transport ventilator should be able to deliver a preset tidal volume in the face of changing lung compliance. Tidal volume can be determined by setting inspiratory and expiratory times along with flow rates. This characteristic will allow transport crew to provide varying inspiratory/expiratory ratios (I/E ratios) and if necessary inverse I/E ratios.

When utilized in the pressure-driven mode, the ventilator should be able to control driving pressure and purge excess airway pressure through preset safety valves. Since PEEP is often required to maintain oxygenation in the critically ill patient, the transport ventilator should have variable PEEP control. In addition, if non-invasive positive pressure ventilation is utilized during transport, the transport ventilator must be able to adapt to non-invasive modes of oxygenation and ventilation.

Critical care transport crews must be proficient in manipulating a mechanical ventilator with changing altitudes. As barometric pressure decreases with altitude, the volume of gas in the ventilator system increases. Constant attention to volume and pressure alterations with in-line volume and pressure monitoring is essential. In order to maintain consistent tidal volume and pressure, transport crews must be prepared to make necessary ventilator adjustments.

Oximetry and capnography are useful adjuncts to the maintenance of adequate oxygenation and ventilation during critical care transport with mechanical ventilators. Continuous assessment of oxygenation with pulse oximetry can alert the transport crew to detrimental changes in oxygenation. Assessment of expired carbon dioxide, using either sidestream or mainstream sensor technology, can be utilized as a quantitative measure of ventilation (also as an ongoing indicator of endotracheal tube location). Capnometry (display of a number) and/or capnography (display of a graph) facilitate the transport crew’s capabilities for early detection and correction of ventilatory abnormalities.

Ventilator oxygen consumption rates should also be considered when a transport program is choosing a mechanical ventilator. Most transport ventilators are designed to utilize oxygen under pressure as the method of driving internal component function. As these ventilators consume large amounts of oxygen, liquid oxygen (LOX) systems are recommended. LOX systems, which weigh approximately 45-50 lbs., allow for significant expansion of oxygen-carrying capacity — a 10,800cc LOX container has the same amount of oxygen as 16 E-cylin-
NITRIC OXIDE THERAPY

A special-case ventilator situation is the neonate receiving inhaled nitric oxide (NO) therapy, usually encountered by critical care teams providing transport to extracorporeal membrane oxygenation (ECMO) centers. As has been noted by those experienced in its use during transport, intratransport NO administration can be a key mechanism to optimizing patient outcomes.23 NO administration, in conjunction with ventilatory support and other appropriate treatment modalities, is indicated for the treatment of term or near-term neonates (>34 weeks gestation) with hypoxic respiratory failure associated with clinical or echocardiographic evidence of pulmonary hypertension. In this neonatal population, NO has been shown to improve oxygenation and reduce the need for extracorporeal membrane oxygenation (ECMO). NO should not be used for neonates who are known to be dependent on right-to-left shunting of blood. (NO delivered by nasal cannula may occasionally be used in pediatric and adult patients.)

Setup of the NO ventilation system depends on the equipment being used. Preparation of the equipment is generally the responsibility of a respiratory care practitioner or equivalent person. Regardless of the specific device used, when NO therapy is initiated by the transport team, the initial dose is usually 20 ppm. Patients who are receiving clinical benefit at a referring facility from a dose other than 20 ppm should be transported receiving that same dose of NO (though there is a generally recognized maximum dose of 80 ppm).

As is the case with other equipment in critical care transport, there are multiple options for delivering inhaled NO, and the needs of a particular program should be integrated with local preferences to determine the best equipment choice. For example, the INOvent™ NO administration system delivers a constant concentration of NO into the inspiratory limb of the patient breathing circuit. The system may also be used to deliver a constant concentration (20-80 ppm) of NO for inhalation through a manual resuscitation bag. The INOvent™ provides a continuous display of the set NO concentration and continuously depicts concentrations of NO2 and NO3.

Environmentally permitted exposure limit (PEL) for NO is set by the EPA at 25 PPM for 8-10 hours continuously. Short-term (15 minutes) exposure is limited to 100 ppm. The PEL of NO2 is limited to 5 ppm. Boston MedFlight has demonstrated OSHA-safe levels in both the rotor-wing and the fixed-wing aircraft when NO is administered during transport (up to and exceeding 80 ppm). Scavenging is not required.

Accidental disconnection from NO can result in sudden, severe hypoxemia and pulmonary hypertension; special care should be taken to prevent disruption of the NO ventilation circuit during patient transfers. For any sudden changes in pulse oximetry, all NO connections should be carefully checked. In manual resuscitators which are unused for a few minutes, NO can be converted into NO2. Resuscitators that have not been used for several minutes must therefore be squeezed 5-6 times to clear any NO2 before ventilating the patient.

If possible, the transport crew should document whether the patient had an initial response to NO (whether it was first administered by the transport crew or by personnel at the referring institution). This data point is potentially important as a predictor of rebound hypoxemia upon NO discontinuation; rebound hypoxemia appears to be more likely in those who initially do not respond to NO.
Regionalization of care and the development of tertiary care centers have resulted in expanded need for interfacility transport of the critically ill patient. An air or ground medical transport program that decides to transport these patients must be able to provide advanced critical care at the bedside and during all phases of the transport process. The provision of this advanced care is optimized through flexible and patient-based crew configuration, broad-based training programs, well-considered patient care guidelines, and appropriate equipment selection. Communications between referring, receiving, and transport personnel are integral to smooth execution of interfacility critical care transport. Conversations before transport allow for optimal pre-transport planning. Lines of communication during transport maintain the opportunity for flexibility and responsiveness to individual patient circumstances. Finally, post-transport communications, in the form of quality assurance and utilization review processes, will help assure ongoing improvement in a system’s approach to interfacility critical care transport.

REFERENCES


SUGGESTED READING

AIR MEDICAL SAFETY: YOUR FIRST PRIORITY

INTRODUCTION

It doesn’t matter who “you” are. If you are involved, or interested enough, in air medical transport to be reading this book and this chapter, you likely appreciate the importance of safety in the medical transport environment. The safety of air medical transport rests with each and every individual who participates in every aspect of a transport—from the communications specialist, the medical team, the aviation professionals, and program leadership, to the referring and receiving personnel. Putting the safety of our patients and our crews first is your responsibility.

It has been said, “Knowledge comes from experience and experience comes from poor outcomes.” If this is indeed true, helicopter EMS (HEMS) has had more than enough experience throughout our history—especially since 1998—to gain a wealth of knowledge. Yet we continue to have accidents at an alarming rate.

Have we gained enough experience and knowledge to prevent these accidents? Have we adequately identified the risks and done everything possible? If there is any hesitation in your response to these questions, there is more that can be done in the interest of safety to avoid unnecessary risk and to take proactive steps to control risk.

RISK ASSESSMENT

There are routine risks with potentially serious consequences with everything we do. Every occupation we choose, every mile we travel, every food we eat, and every hobby we enjoy, all may be associated with some level of risk. At some point, we must make a decision as to whether a particular risk is acceptable.

Acceptable risk is a relative concept. In weighing the pros and cons, an individual has to be knowledgeable and familiar with the risk or activity. One has to consider the certainty and severity of the risk and the reversibility of any health effect. An important consideration, depending on the situation, is whether the risk is voluntarily accepted or involuntarily imposed. Finally, the advantages of the activity must be considered as well as the risks and advantages for any available alternatives.

Quality experts often believe that “you can’t manage what you can’t measure.” Therefore, understanding the magnitude of the risk involved in HEMS is essential in determining acceptable risk as well as how to manage that risk.

NTSB REPORT, 1988

In 1988, the National Transportation Safety Board (NTSB) released a study that evaluated “Commercial Emergency Medical Service Helicopter Operations.” This report came at the time of our industry’s highest accident and fatality rate. While the number of flight programs more than tripled from 1981 to 1986, there was also a dramatic increase in the number of accidents.

The NTSB studied 59 commercial HEMS accidents that occurred between 1978 and 1986. Nineteen of these accidents resulted in fatalities, taking the lives of 53 people. From 1980 to 1985, the NTSB reported an accident rate of 12.34 accidents per 100,000 hours of flight—nearly double that of nonscheduled Part 135 (“air taxi”) helicopter operations. It was also determined that the HEMS fatal accident rate was 5.40 per 100,000 flight hours, or nearly 3.5 times higher than other nonscheduled Part 135 helicopter operations.

The NTSB identified four major factors related to these accidents: human error (68%), weather (30%), mechanical failure (25%), and obstacle strikes (20%). The NTSB report also recognized several disturbing trends in HEMS operations. Increased competition could result in an emphasis on transport volume rather than flight safety. Pilots might feel pressure (self-imposed or externally imposed) to accept and complete flights despite marginal weather conditions. Pilot training was often deficient in interpretation of weather conditions and in instrument flight procedures. The NTSB also determined that modified EMS interiors and program practices often compromised crashworthiness standards, resulting in an increased risk of injury and death.

The NTSB report made specific recommendations to the FAA and to the American Society of Hospital-Based Emergency Air Medical Services (ASHBEAMS— the original name of what is now the Association of Air Medical Services). Their recommendations included: improved interior modifications that would not compro-
mises crashworthiness; the use of shoulder harnesses and protective clothing (e.g., helmets, flame-resistant suits, protective footwear); the development of program safety committees; improved training in marginal weather operations, emergency procedures, pilot-crewmember coordination, and communications.

How did "we" respond and address the safety concerns and these recommendations? We saw an increase in safety committees, improved Instrument Flight Rules (IFR) training, improved weather information, less pressure to fly, 4-pilots per helicopter, various aircraft improvements and other safety initiatives. And we saw a decrease in accidents—but not for very long.

**ORIGINAL RESEARCH**

In 1996, there was only one HEMS accident, and in 1997, there were three. Then, in 1998, HEMS saw the beginning of an alarming accident trend with eight accidents. There were ten in 1999 and twelve in 2000. "We" began to ask questions and look for answers—as an industry, as programs, as individuals.

During the fall of 2000, the University of Chicago Aeromedical Network (UCAN) Safety Committee began an extensive investigation and safety research project. Our efforts culminated—at least for the moment—in November 2002 with the AMPA publication and industry-wide distribution of A Safety Review and Risk Assessment in Air Medical Transport.

Meaningful data was lacking in HEMS. For more than a decade, the only available information was the number of accidents and fatalities—the raw numbers. There was no collective information on total annual flight hours or the number of patients being transported each year. Accident rates were not obtainable. There wasn’t even an accurate accounting to report the number of HEMS programs or HEMS helicopters in operation.

Despite the general lack of readily available data, our original research was able to determine the magnitude of risk by identifying for the first time in 14 years the HEMS accident rates, fatal accident rates and death rates. In addition, a comparison of risk was made to other operations, high-risk activities and various daily activities.

**FOCUSED ANALYSIS: 1998-2005**

Our analysis of HEMS accidents has continued with a focus on what has occurred since 1998 and how that compares or relates to our entire accident database dating back to 1972.

An initial review of the data made it necessary to reevaluate the inclusion and exclusion criteria for our database of accidents. While the NTSB provides definitions for "accident" and "incident," there remains no consensus as to what constitutes a HEMS accident. This remains up to individual data collectors and researchers. In our 2002 study we included aircraft that were in-service or available to the crew for a mission. We included dedicated aircraft, dual-purpose aircraft, patient and non-patient missions, "PR" flights, refueling and repositioning. We chose not to include fixed-wing accidents, international accidents, military accidents, HEMS aircraft that were not in service (i.e., maintenance flights while another aircraft was in service), non-dedicated aircraft, and any "as needed service" using non-HEMS aircraft for transplant teams, etc. Initially, we did not include training missions, as it could not be confirmed if the aircraft were in-service or not. There were two training accidents identified prior to 2002. However, since our initial report, there have been a total of seven training accidents identified over a four-year period. While the aircraft involved might not have been in-service and our dedicated helicopter not at risk, clearly our pilots were in harm’s way. Therefore, an adjustment to our inclusion criteria was deemed necessary.

From 1972 through 2005 we identified 224 HEMS accidents (Figure 56-1). This includes 218 dedicated HEMS aircraft and 6 dual-purpose aircraft. A total of 84 of 224 accidents resulted in at least one fatality. The accidents involved 653 individuals on board the helicopters. There were 224 fatalities, among them pilots, nurses, physicians, paramedics, respiratory therapists, patients, family members, police officers, firefighters, and observers. There were also 66 serious injuries, 91 minor injuries and 272 individuals who were uninjured (Figure 56-2).

Looking at our focused interval (1998-2005), there were 107 HEMS accidents, or 48% of all HEMS accidents since 1972. Dedicated HEMS accounts for 104 of the accidents and 36 (of 107) accidents were fatal. These 107 accidents included 310 individuals, of which 90 suffered fatal injuries: 75 HEMS crewmembers, three dual-purpose crewmembers, nine patients and three others. There were 34 serious injuries, 34 minor injuries and 152 uninjured.

The past eight years have seen a dramatic increase in the number of HEMS accidents across the nation. From 1998 to 1997, dedicated and dual-purpose HEMS averaged 5.0 accidents per year. Since 1998, we are averaging 13.4 accidents per year. Our 2002 analysis shows an average of 10.75 accidents per year from 1998-2001.

Of the 107 accidents from 1998 to 2005, 36 (34%) resulted in at least one fatality. For the 1980s, our accident database showed 39% of all accidents resulted
in at least one fatal injury. From 1990-1997, the rate increased to 47%. Despite the high number of accidents since 1998, the percentage of fatal accidents has fallen by nearly 30%. Figure 56-3 depicts the percentage of fatal accidents each year since 1980. As the figure shows, the last eight years have had the lowest consecutive percentage of fatal accidents over any 8-year period since 1980.

**HEMS DATABASE**

Our 2000 to 2002 research was hampered by an overwhelming lack of data with regard to annual flight hours, patients flown, number of HEMS programs and HEMS helicopters. Our research model enabled us to fill in the gaps and enabled us to estimate that HEMS had flown (1972-2001) an estimated 3.0 million hours while transporting approximately 2.75 million patients. For the year 2001, we estimated that there were 231 programs operating approximately 400 dedicated helicopters.

Our follow-up research in 2005 was somewhat easier as we now had two Internet databases available. FlightWeb's *Air Medical Transport Registry* (AMT-R, available at http://www.flightweb.com/AMT-Registry) and the Atlas and Database of Air Medical Services (ADAMS, available at http://www.adamsairmed.org/) provided valuable program information. Missing still, however, was any database that tracked total annual flight hours or patients transported for the entire air medical industry. Despite this hindrance, with our safety research and credibility established, our operator survey was easier to complete and was expanded from five (in 2002) to now include the nine largest HEMS operators in the United States. Each operator was asked to complete a survey that included data fields for 1998 through 2004; the data fields included:
Air Medical Physician Association

- Total number of programs (at the end of their statistical yr)
- Total number of dedicated helicopters (at the end of their statistical yr)
- Total flight hours for the year
- Backup helicopters (for entire fleet, at the end of their statistical yr)
- Night flight (% or hrs)
- Scene response (%)
- The number of independent provider or alternate delivery model programs
- The number of independent provider or alternate delivery model helicopters

Data available from the AMT-R, ADAMS and our own personal database verified in dramatic fashion the growth that had been evident in just a few years (Figure 56-4). As of September 2005, we identified a total of 270 dedicated HEMS programs operating 585 dedicated helicopters. The industry growth since 1998 (219 programs, 343 helicopters) was a 23% increase in programs and a 71% increase in dedicated aircraft! Historically, since 1886, the number of aircraft has doubled every 9 to 10 years. In 1986, there were 151 helicopters. By the end of 1995, that number had grown to 293. Near the end of 2005, the number had again doubled to 585 dedicated helicopters.

It is important to note that the database and numbers described in Figure 56-4 include dedicated HEMS programs and aircraft and do not include dual-purpose or military assets. The three-year-old ADAMS database, however, best tracked this growth that included all business models and types of operations (dedicated, public use and military). Their database included 243 services, 472 base of operations and 545 helicopters in 2003. Two years later, there was a slight growth in services to 272, but a dramatic increase to 614 bases and 753 helicopters (Figure 56-5).

From the AMT-R, we evaluated the breakdown of “programs” and helicopters as of October 2005. One thing that became obvious was that the “typical program” was no longer easy to define. For decades, the “typical” helicopter program was a hospital-based or hospital consortium operation of one to several helicopters. In recent years, a change emerged as more independent operations sprang up and individual programs covered huge geographic areas and often multiple states with many, many aircraft.

Our 205 nine-operator survey identified that, as of 2004, single hospital sponsored programs remained the most common business model (45%). This is followed by the independent providers (27%), then by multiple-hospital consortiums and public services, each account-
ing for 13% of the programs. The military (mostly in Alaska and Hawaii) represented 2% of the programs (Figure 56-6).

When the focus shifts from programs to aircraft, however, the landscape is very different (Figure 56-7). Independent provider models now account for the highest percentage of medical helicopters with 40%. Single hospital sponsored programs, which accounted for 45% of the programs, account for only 28% of the aircraft, while public use aircraft represent 15% and consortia 14%. The military accounts for 3% of the helicopters.

Our survey of the nine largest operators yielded a total of 457 dedicated helicopters in service for 206 programs at the end of 2004. Both of these variables were tracked for our focus period beginning in 1998. Over the 7-year period, there was a 36% increase in the number of programs and a 70% increase in the number of helicopters operated by the combined group of operators. (Figure 56-8).

From the operator survey, we also collected information on total flight hours, night flights and scene re-

sponses. We compared the number of helicopters in operation industry-wide from our database to the number of aircraft operated each year by the combined survey group. During 1998 to 2004, the operators accounted for 78% to 91% of the aircraft in operation each year. This provided us with a high degree of confidence that our sample "group" data would correlate well with the entire industry.

With the significant growth in the number of helicopters in service, there was speculation as to what impact this was having. Some questioned whether the new programs and aircraft were simply taking flights away from "existing" programs and aircraft or if more patients and more flight hours were being flown.

To address this, we evaluated four different data-points: average flight hours per program, average flight hours per helicopter, total HEMS flight hours per year, and total patient flown per year.

**ANNUAL STATISTICS**

The information in Figures 56-9 and 56-10 represent data from our original 2002 study as well as our new research. The total flight hours for 1980 through 1985 were figures that had been published in *Air Med*, one of the predecessors to what is now known as the *Air Medical Journal*. Information for 1986 through 1997 was based upon our 2002 calculations, which relied upon various *Air Med* Annual Transport Surveys. A problem with relying on these surveys was the percentage of surveys returned each year, which ranged from a high of 96% to a low of 33%. In general, the annual results were fairly consistent. The one exception was 1994, which had significantly higher average flight hours per program and much lower loaded miles than other years.

Data for 1998 through 2004 was based upon our updated operator survey, which consistently accounted
for a very high percentage of the industry's programs and helicopters. Figures for 2005 were estimated based upon partial year data that was available (number of programs and helicopters) and averaged flight hours for the previous three years.

Understanding the changes noted in the number of programs vs. helicopters, it is not surprising to find that the average flight hours per program, in general, were steadily increasing since 1998. The typical ratio of helicopters to programs in 1998 was just over 1.5:1, and by the end of 2004, it was nearly 2:1.

The most valuable information would seem to be with the average flight hours per helicopter. Based upon our operator survey, there was no noticeable decline in flight hours per helicopter since 1998, while the number of aircraft continued to increase. In fact, there was a gradual increase in the number of hours per aircraft (Figure 56-10). With the exception of the early 1990s, flight hours since 1980 (when there were fewer than 100 helicopters) have remained steadily between 500 to 600 hours per helicopter.

The total flight hours per year nationwide showed that we surpassed an annual rate of 300,000 flight hours (Figure 56-11). It was also estimated that since 1972, dedicated HEMS has flown nearly 4,000,000 flight hours.

Estimating the number of patients transported with accuracy is more difficult than the evaluation of flight hours. Relying upon the data we collected in 2002 and our calculated total of 0.98 flight hours per patient transported, we estimated the patients transported per year as seen in Figure 56-12.

**FINDINGS: 1998-2005**

Our operator survey also facilitated the analysis of HEMS accidents. In addition to the totals already identified, we queried the operators about night flights and scene response flights.
CHARACTERISTICS OF HEMS ACCIDENTS

We continue to see a disproportionate number of HEMS accidents occurring during night operations. From our operator survey, 35% of an estimated 1.4 million flight hours (annual range of 32-36%) were at night. However, 47% of the accidents during our focus years (1998-2005) occurred during night operations. Our 2002 report cited that since 1988, the range of night operations had been between 35 to 42%, with an average of 38%. Rick Frazer’s 1999 report, “Air Medical Accidents: A 20-Year Search for Information,” published in *AirMed*, reported that 49% of the HEMS accidents over 20 years occurred during night operations.

Scene transports also accounted for an inequitable number of HEMS accidents. From 1998 through 2004, our operator survey identified that scene response missions accounted for an average of 33% of the annual flight hours (range, 29-35%). In contrast, 48% of the accidents during patient-related missions occurred on scene flights. If all missions had equal risk, 33% of the accidents should have been on scene flights. Frazer’s 20-year report identified 42% of the accidents were on patient missions, while our 2002 report identified 45% of the accidents occurring on scene flights vs. 31% scene missions (average since 1988).

Evaluating National Transportation Safety Board (NTSB) accident reports provides valuable insight into characteristics of HEMS accidents. Considering only those reports that were final, we found that the NTSB attributed the “probable cause” of accidents to be “pilot error” (direct or indirect) in 78% of the accidents. The most common factors were weather-related accidents and collision with objects. In contrast, mechanical-related accidents were cited in 16% of the final reports. In comparison, Frazer had identified “pilot error” as a factor in 65% of the accidents, while 23% were mechanical or maintenance-related.

Again, considering only HEMS accidents that were supported by final reports, 22% of the accidents were found to be weather-related accidents. Fifty-five percent (55%) of weather-related accidents were fatal, compared to 35% of all accidents that had at least one fatality. The finding of 22% was a dramatic turn compared to the 14% we had previously reported for the years 1998 to 2001. Of significant interest, we identified 13 weather-related accidents from 2002 through 2004. Wind conditions (rarely mentioned in the past) on landing were reported to be a contributing factor in several reports. In comparison to our findings, Frazer’s work found 22% of accidents to be weather-related in the 1980s, and 32% in the 1990s. Of note, the 1988 NTSB report found 30% of the accidents to be in poor weather, which they concluded to be the greatest single hazard to EMS helicopter operations.

In-flight collision with an object (CWO) and Controlled Flight into Terrain (CFIT) were found to be significant factors in our accident analysis. CWO is an event that normally occurs in conditions of restricted visibility when the pilot is unable to see an obstacle or the terrain in time to avoid a collision. In contrast, CFIT refers to an event that normally occurs in IFR conditions or at night, generally as a result of loss of situational awareness.

In our study period, CWO was a factor in a total of 28 accidents, or 3.6 per year. Three of the accidents were fatal. CFIT accounted for 15 accidents (2 per year) and 13 were fatal. In total, 43 of 86 accidents—50% of all accidents from 1998 to 2005 with final reports (as of October 2005)—were the result of CWO or CFIT. In stark contrast, Frazer had reported only eight such accidents from 1990 to 1998 (less than one per year) and only 18% of all accidents during that timeframe.

HEMS ACCIDENT AND FATAL ACCIDENT RATES

An important aspect of this study was the continued determination of HEMS accident and fatal accident rates for the defined study period (1998-2005). Calculations to normalize the data for meaningful comparison were based upon the estimated exposure data (i.e., total flight hours) and the known number of accidents in our database. Figure 56-13 shows a gradual increase in the accident rate beginning in 1996 (0.56 accidents per 100,000 flight hours) and continuing through 2000 (6.79 accidents per 100,000 flight hours). The accident rate started to decline slowly before shooting up again in 2003. However, 2004 and 2005 did see a decrease to 4.4 and 4.76 accidents per 100,000 flight hours, respectively.

![Figure 56-13: Accident rate per 100,000 flight hours for HEMS operations, 1980 – 2005.](image-url)

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Considering the average accident rate for 1998-2005 to be 5.47 accidents per 100,000 flight hours, the average dedicated HEMS helicopter flying 575 hours per year would correlate to one accident over 31.8 years of flight time. Taking into account the number of programs or helicopters rather than average flight hours would be another way to consider the likelihood of an accident. Since 1998, there has been an average of 13 accidents each year involving dedicated HEMS aircraft. With 280 dedicated HEMS programs we would predict one accident per program every 20.7 years. If you base this comparison on 585 dedicated helicopters estimated for 2005 rather than the number of programs, the forecast would be for one accident in 45.0 years.

The next calculation determines the fatal accident rate per 100,000 flight hours (Figure 56-14). As with the accident rate, the fatal accident rate declined significantly from the early and mid-1980s to the early 1990s. As would be expected with the increased accident rate, a steady increase in the fatal accident rate began in 1996. For the past eight years, the range has been between 1.52 to 2.09 fatal accidents per 100,000 flight hours per year. With an average of 1.84 fatal accidents per 100,000 flight hours, we would predict that the “typical” HEMS helicopter would suffer one fatal accident while flying more than 94 years.

The fatality rate for HEMS was dramatically higher than all other aviation operations throughout most of the 1980s. In 1990, however, there were no fatal HEMS accidents. From 1992 to 1997, the fatal accident rate for HEMS was consistently below general aviation and all helicopter operations. Unfortunately, with the increase in accidents that began in 1998, we also see an increase in the fatal accident rate. For the past eight years, however, the HEMS fatality rate exceeded all other aviation operations, with the exception of 2003, when the fatal accident rate for all helicopter operations was slightly higher than HEMS (Figure 56-16).

Has there been any real progress since the 1988 NTSB report? Clearly, the accident rate over the past eight years has been better that what we experienced in the 1980s. Unfortunately, the accident rate is consistently higher than it was in the early to mid-1990s. The fatal accident rate follows this trend and remains higher than the rates of the early to mid-1990s.

HEMS COMPARED TO OTHER AVIATION OPERATIONS

In general, there are three major categories of aviation regulated by the FAA. Part 135 corresponds to “air taxi” and is classified as Scheduled or Non-scheduled, which includes air medical transport and other on-demand air taxi services. Part 121 aviation governs the airlines, both scheduled and non-scheduled (charter) airlines. The third category is General Aviation (Part 91), typically characterized by recreational (personal) flying, instructional, business, corporate, public use, and other vital services.

The FAA and NTSB websites have raw data and normalized statistics readily available for the different types of aviation operations (http://ntsb.gov/aviation/Stats.htm). The Helicopter Association International website offers statistics on helicopters (www.rotor.com). With our estimated HEMS accident and fatality rates per 100,000 flight hours, it is possible to compare various types of aviation in a more meaningful way.

The accident rate for HEMS was dramatically higher than for all other aviation operations during the early and mid-1980s. Beginning in 1987, we see a sharp decline in the HEMS accident rate. Since that time, and despite the increase in the number of accidents since 1998, the HEMS accident rate has remained consistently below the accident rates per 100,000 flight hours for general aviation and all helicopter aviation (Figure 56-15). It is, however, higher than Part 135 scheduled and unscheduled operations.

The fatality rate for HEMS was dramatically higher than all other aviation operations throughout most of the 1980s. In 1990, however, there were no fatal HEMS accidents. From 1992 to 1997, the fatal accident rate for HEMS was consistently below general aviation and all helicopter operations. Unfortunately, with the increase in accidents that began in 1998, we also see an increase in the fatal accident rate. For the past eight years, however, the HEMS fatality rate exceeded all other aviation operations, with the exception of 2003, when the fatal accident rate for all helicopter operations was slightly higher than HEMS (Figure 56-16).

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THE POPULATION AT RISK

In 2002, we attempted to quantify the magnitude of risk to the air medical crew. To normalize the data, it was necessary to know two numbers: the number of individuals either injured or killed each year; and the number of people engaged in that activity (i.e., the population at risk). Therefore, comparing air medical transport to other occupations or “routine” risks to determine the odds of death in one year or the fatality rate per 100,000 individuals (the most common comparison) made it necessary to estimate the number of people engaged in HEMS transport (i.e., the number of HEMS...
Figure 56-15: Accidents per 100,000 Flight Hours, 1982-2005.

Figure 56-16: Fatal Accidents per 100,000 Flight Hours, 1982-2005.
pilots and medical crewmembers) for each year. The number of fatalities is known, but the number of crewmembers in HEMS had never been tracked.

For the 2002 study, the average number of crewmembers per helicopter was estimated to be 22 persons (4 pilots, 6-8 nurses as the primary caregivers, and 10-12 second medical crewmembers). For 2001, with approximately 400 dedicated medical helicopters, there was an estimated population at risk of 8,792. Having estimated the number of helicopters for each year, the number of crewmembers was approximated for each year.

In 2005, with the availability of the AMT-R and ADAMS, a decision was made to either validate our initial calculation (using 22 persons per aircraft) or to determine the population at risk more accurately. We accomplished both goals. Looking only at programs that provided HEMS transport without a fixed-wing transport component, we identified 48 programs that were a single helicopter operation. Indeed, the average number of crewmembers (pilots and medical crew) was 22 per program (i.e., per helicopter). However, one aspect we had not considered in 2002 was the staffing implications of a multiple helicopter program. What we found was that the more helicopters a program had, the fewer individuals the program employed on the average per aircraft. There were 41 programs operating two rotor-wing (RW) aircraft, with an average crew complement of 18 individuals for each RW. Eight (8) programs operating three RW were identified, with an average of 16 crewmembers per helicopter. There were also eight (8) programs with four RW aircraft in service. Their average number of crewmembers per aircraft was down to 15. Finally, eleven (11) RW programs, each operating five RW aircraft, had an average of 12 employees per helicopter. With the wide variation, the decision was made to use the average for the 105 programs operating 186 helicopters, which yielded 18 crewmembers per aircraft. Thus, the population at risk for 585 aircraft in 2005 was calculated to be 10,530. With no information available to determine how many programs operated the various numbers of helicopters each year, a decision was made to recalculate every year to reflect this new estimate per RW. As a result, 2001 now was estimated to have a total population at risk of 7,200, rather than our original approximation of 8,792.

In estimating exposure in this method, it does so for the average crewmember and the average flight program. When the raw data are normalized, it does not take into account the amount of exposure for an individual over the course of the year. Everyone is considered to be at equal risk.

FATALLY AND DEATH RATES

To be consistent with statistics from the National Safety Council (NSC), the HEMS data would need to be normalized to produce a death rate per 100,000 populations at risk for each given year. First, the number of crew fatalities was determined for each year (Figure 56-17). Over the 26 years reviewed for this portion of the study (1980-2005), the HEMS population has grown from approximately 702 to 10,530. While this growth seems significant, this remains a very small sampling to convert to a ratio per 100,000. With such a small population at risk, each fatality will have a substantial impact on the fatality rate. The calculated range for the HEMS crewmember fatality rate is 0 to 855 fatalities per 100,000 persons (Figure 56-18). With such a wide range, a 26-year average was calculated, yielding an average annual death rate of 231 per 100,000 crewmembers. Looking only at our focused interval of 1998-2005, the annual fatality rate is much lower compared to the experience of the 1980s. There is a much closer range of 28-175 fatalities per 100,000 crewmembers, with an 8-year average of 120.

![Figure 56-17: HEMS Crew Fatalities per Year, 1980-2005](image)

![Figure 56-18: HEMS Fatality Rate per 100,000 Personnel, 1980-2005](image)
To further illustrate the risk related to HEMS transport, we compare our calculated fatality rate to other types of accidents and other causes of death. Taking into consideration the wide range of fatality rates that we have estimated for each year in HEMS, the calculated average for 1998-2005 is used in subsequent comparisons.

In 2004, the death rate per 100,000 for all accidental deaths was approximately 36. Motor vehicle accidents were the highest in this category with 15 deaths per 100,000 individuals. When one considers the average annual death rate (120) for HEMS crew members over the 8-year period, HEMS crew members are eight times more likely to suffer a fatal injury in a helicopter accident than in an auto accident. Considering all age groups, however, there is twice the risk of dying from heart disease. (Figure 56-19)

<table>
<thead>
<tr>
<th>Cause of Death (in rank order)</th>
<th>Death Rate Per 100,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Causes, all ages</td>
<td>848</td>
</tr>
<tr>
<td>Heart Disease</td>
<td>246</td>
</tr>
<tr>
<td>Cancer</td>
<td>194</td>
</tr>
<tr>
<td>HEMS</td>
<td>120</td>
</tr>
<tr>
<td>Stroke</td>
<td>57</td>
</tr>
<tr>
<td>All Accidental Deaths</td>
<td>36</td>
</tr>
<tr>
<td>Motor-vehicle</td>
<td>15</td>
</tr>
<tr>
<td>Falls</td>
<td>5</td>
</tr>
<tr>
<td>Poisoning</td>
<td>5</td>
</tr>
</tbody>
</table>

Figure 56-19: Adapted in part from: National Safety Council, Injury Facts 2004 Edition

HEMS: IS YOUR PATIENT AT RISK?

Healthcare is risky. The results of two comprehensive studies have suggested that between 44,000 and 98,000 Americans die in hospitals each year as a result of medical errors. Normalizing these numbers produces a death rate between 131 and 292 per 100,000 patients due to medical errors. The NSC, however, provides statistics on “complications of surgery/medical care” that is based upon the reported number of deaths compared to the entire U.S. population. Their finding of 1.2 deaths per 100,000 individuals is dramatically different.

Air medical transport is not a medical treatment and aviation accidents would not be considered a medical error. However, we could argue that these accidents represent an adverse event in a healthcare environment. In our 26-year study, we estimate a total of 3,953,000 patients have been flown by HEMS. Over this same time period, 27 patients have lost their lives in HEMS accidents. This would be consistent with a death rate of 0.68 per 100,000 patients flown. Based upon this calculation, one might conclude that there is a far greater risk to the patient of dying from an adverse event once hospitalized than from an aviation accident when transported by medical helicopter.

RISK MANAGEMENT IN HEMS

To most air medical professionals, AMRM brings to mind Air Medical Resource Management. An alternative would be for AMRM to correspond to Air Medical RISK Management!

Four basic principles should guide the coordination, implementation, and evolution of a safety and risk management program for air and ground medical transport operations. These principles include: attitude, participation, education, and judgment. Simply stated, everyone must have the right attitude about safety, everyone must participate. A proper education is a key ingredient in identifying, understanding, and actively managing risk. Finally, sound judgment is necessary to pull it all together; to recognize and analyze all pertinent information in a particular situation; and to evaluate alternative actions in a timely manner.

There are six risk management techniques that can be used to control risk. These techniques, which often overlap, include:

- Risk Retention
- Segregation of Risk
- Risk Transfer
- Risk Avoidance
- Risk Prevention
- Loss Reduction

RISK RETENTION

The first consideration is Risk Retention. To some, this may not seem like much of a risk management technique, as a program or individual consciously assumes the risk and takes no specific action to reduce the risk or the severity of a loss. However, risk retention may be the only available option when the other strategies cannot be considered for whatever reason.

There are two forms of risk retention. The first is intentional or by design—deciding that other available techniques are not suitable and it is necessary to retain the risk of harm or loss. Problems often occur when risk is retained unintentionally. This can be the result of failing to understand the scope of a risk or simply because no one has taken the time to consider the risk and how it can be addressed.
SEGREGATION OF RISK

Under this option, a program may attempt to reduce the likelihood of a loss, but does nothing to prevent an accident from occurring. A program may choose to have separate helipads for its multi-helicopter program or for a visiting aircraft to use. If a helipad accident or incident were to occur, there is less chance of involving more than one aircraft. Some families employ this when traveling on commercial airlines. Rather than an entire family flying together on one airplane, the family will split up, taking separate flights.

RISK TRANSFER

The third alternative is Risk Transfer—someone else assumes the risk, often under the terms of a contract. In HEMS, this might include not having a flight program or having another flight program undertake your transports. In the past few years, several traditional hospital-based programs have engaged this option for various reasons. They have either closed their programs or turned them over to a different business model (alternate delivery model or independent provider model). The choices of a Part 135 operator vs. operating your own 135, insurance and power-by-hour are all examples of risk transfer alternatives.

RISK AVOIDANCE

If you can avoid exposure to a risk—or certain aspects of a risk—there is less chance for that risk to have an effect on your program. In some ways, this is similar to risk transfer. However, instead of transferring a risk completely, decisions are made or policies are in place to avoid the risk associated with a specific task or activity.

Some air medical programs triage every flight request to determine the appropriateness of the request in order to determine to accept a flight or for air vs. ground transport. A program could also decide that scene accidents or flying at night pose too great a threat and elect to avoid these situations. Some programs or operators may elect to have more restrictive weather minimums. Deciding not to have a ride-along program, not allowing family members to accompany a flight, or not doing “PR” flights are other types of risk avoidance.

Some European countries avoid the risk associated with night flight and only fly missions during daylight hours. One could argue that if we took a similar approach, we could eliminate 47% of our HEMS accidents, which corresponds to the percentage of accidents during night operations in our focus years of 1998-2005. One could also debate that we could eliminate 53% of the accidents if we did not fly during the day and only flew at night!

An important aspect of risk avoidance is to evaluate the affect it will have on your operation. If a program chooses to “avoid” scene responses, certain low lighting conditions or flights in marginal weather, what will your competition do? What will your requesting agencies do? Will competitors rush in to fill the void—the flights you turn down—and gain a foothold in your market? Beware, there will be times that risk management concerns and business decisions will go head-to-head!

RISK PREVENTION

When risk cannot be avoided completely, the frequency and severity of a loss can often be minimized by taking steps to prevent an undesired outcome or to reduce the extent of the loss. Risk prevention represents one of these considerations. In this situation, the HEMS program would take the necessary action to try to prevent a loss through comprehensive training (pilots, medical crews and communication specialists), policies and procedures, and so on. Again, there is some overlap with risk avoidance. For example, a helicopter program may choose to do scene flights only during the day or only land at pre-designated landing zones. A program may also conclude that a twin-engine aircraft is less likely to have a potentially catastrophic malfunction (i.e., engine failure of a single-engine helicopter) or that two pilots will reduce the likelihood of pilot error. The use of new technologies for terrain avoidance, automated flight following, and aided night vision are also important considerations. All of these options strive to decrease the possibility of an aircraft accident, but do not eliminate all possibility of an accident occurring.

The importance of comprehensive training and adherence to policies and procedures cannot be over emphasized in what we consider our Strategy #1: Reduce the Most Accidents. A focus must be on Air Medical Resource Management that addresses the importance of complacency and carelessness (C³). It may be very difficult to differentiate between complacency and carelessness. However, our 1998-2005 focused review identified 35 of 115 (32%) accidents and incidents that we could attribute to these C³ offenses. Our findings attribute more accidents to the combination of complacency and carelessness than to weather-related accidents (22), collisions with objects (28) or controlled flight into terrain (15). Often, the specified actions that we classified in this manner were attributed by a NTSB report to the pilot. Other times, reference was to the medical crew, mechanics, or ground personnel. Examples from the NTSB reports include:
Principles and Direction of Air Medical Transport

- Failing to secure cowlings, latches and items
- Failure to identify ground hazards and clearance
- Failure to follow company policy
- Distractions
- Failure to refuel
- Failure to follow the checklist
- Improper planning, pre-flight or decision making
- Inadvertent activation of switch
- Medical crewmember requesting “more than once for the pilot to abort the flight”
- “Site-seeing”

Our next risk prevention approach is Strategy #2: Save the Most Lives. Technology and training are factors that have contributed to the improved safety of commercial aviation. The reduction in fatal air medical transport will likely also rely upon these factors—especially technology.

Visually Challenged Flights account for a very high percentage of HEMS accidents. In our 1998-2005 review, 43 accidents (50% of those with an NTSB “Probable Cause”) involved collision with objects (CFIT and CWO). There were 15 CFIT accidents, of which 13 were fatal. CWO accidents totaled 28, with three fatal. Accidents that took place during night flights accounted for 49 accidents, or 47% of our focused evaluation; 23 of these were fatal. There were 22 weather-related accidents (24% of those with final NTSB reports), of which 12 had at least one fatality.

Aviation professionals and aircraft completion experts may look at available technology differently—and with different terms. However, our approach to counter the deadly effects of visually challenged flights is through vision technologies: avoidance systems; vision systems; weather information systems; and automated flight following.

Avoidance systems include avionics designed to alert a pilot of potential hazards from obstacles, obstructions, or terrain. This category also includes traffic avoidance or warning systems. Vision systems include the various enhanced vision systems that are available, including night vision goggles. Enhanced vision systems have been used by the military for decades, but their acceptance and integration into civilian HEMS has been very slow. Newer technology and options in weather information systems can enable the pilot to “see” more and better weather information, especially when flying cross-country to areas that previously had little, if any, weather reporting capabilities. Finally, automated flight following allows the communications center to “see” the aircraft location more accurately and more frequently than traditional flight following.

**LOSS REDUCTION**

The final risk management strategy is loss reduction, which attempts to reduce the loss potential and decrease the severity of the loss. This strategy is best used in conjunction with other risk management strategies, since using this method alone will not totally eliminate the risk. The decision to wear helmets or Nomex is a loss reduction technique in HEMS. Survival training and appropriate survival gear may also reduce the losses in an accident, but do nothing to prevent an accident from occurring.

Each program should pay special attention to the appropriateness of the survival gear that its members select—and where it is stored. The traditional, well-supplied survival bag that is stored in the tail boom will be of no use if the crew can’t get to it after an accident. Instead, many programs utilize personal survival kits that are carried by each crewmember. Included in these kits must be adequate signaling and communications devices. There have been numerous accidents in recent years in which a crewmember used a mobile phone to contact his or her communications center to inform them that they had just crashed and to help direct rescuers to the location. Personal survival kits and cell phones are strongly recommended!

**CONCLUSION**

This chapter has provided a detailed look at the risk of HEMS. The risks associated with HEMS are significant—as are the benefits. We have the ability to save lives—and take them. We have the ability to make a difference—each and everyone of us.

While this chapter offers various risk management strategies, it does not provide the definitive solution to a safer industry. This chapter does not, and cannot, answer all your questions. How do you best manage your risk? Are you making the right decisions? What can you do that will make a difference? Who will be next? What will you do if that next page or phone call you get is to tell you of an accident—or a fatal accident? Then there are other questions. What could you have done differently? What should you have done differently? What will you do differently?

No matter what we do, we still have more questions than answers!

We all need to learn, relearn and live the basics of safety, each and every day, and each and every flight. It is important to learn from each and every “opportunity” and to share the knowledge with the industry—or the community. We must manage our risk exposure through
appropriate utilization and by embracing new technology.

Coach John Wooden once said, "Don't let what you cannot do interfere with what you can do." Consider your options. Consider the consequences. Consider the consequences if you do nothing.

When my daughter started kindergarten she came home with a flyer that said, "Stop, think and make a good choice." Perhaps it's as simple as that. Make good choices... each and every day. Don't be the next accident.

Make safety your first priority!

ACKNOWLEDGEMENT

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SUGGESTED READING