Aeromedical Flight Crew Manual

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Preface

The transportation of sick and injured patients by aircraft has evolved over one hundred years. The safety of this method of patient travel - of literally millions of patients, confirms the efficacy of aeromedical evacuation. There are various methods and types of aircraft that can be used. The speed, distance, and terrain that these airplanes traverse will be discussed in detail. The medical flight crew must understand the dynamic aerospace environment and its impact on patient care. Topics to be discussed include: flight physiology, stresses of flight, mission management, aeromedical safety, legal implications of air ambulance transport, and flight crew considerations.

Long distance medical transportation in conventional airplanes has many advantages over other methods of travel. But aeromedical transport involves more than placing a stretcher onboard an airplane and flying the patient to his/her destination. There are several considerations before moving patients by air. The most basic idea is that man is adapted for life at sea level and the aviation environment presents some real dangers to sick or injured individuals. For example, patients with abdominal distention or pneumothorax need pressurization and special handling. Equipment such as intravenous lines may not function properly at altitude and temperature differences may affect the patient. The flight crew must recognize the problems of altitude and adjust patient care as needed.

This manual addresses the fundamental principles of aerospace medicine and assumes that the reader has a basic understanding of pathophysiology and patient care. It specifically addresses in-flight care and is directed toward nurses and other health care professionals who wish to gain insight into aeromedical transport. This manual is appropriate for any flight team member including, EMT's, Paramedics, Respiratory Therapists, Physician's Assistants, and Physicians who may participate in transporting patient by air.

The Aeromedical Flight Crew Manual is the training document for the flight team of National Medevac, a fixed-wing air ambulance company based in Charlotte, NC. I found that there was no "off the shelf" text that addresses the basic concepts and practical problems of aeromedical transport aboard conventional aircraft. I developed the following document after extensive research of the literature and compiled over fifty years of objective research and journals. See the bibliography for an overview and outline of subject. I published this book and offer it to my flight crew colleagues who are interested in learning more about the environment we dare to challenge each day.

The material presents a comprehensive overview of the theories and problems encountered during patient transportation. The material is factual but no warranties or guarantees are made or implied regarding the clinical adequacy of this book. Any person wishing to use this material in actual practice should carefully consult with a physician knowledgeable in aerospace medicine.

One Hundred Years of Aeromedical Transport

It is inconceivable that medical evacuation by air would predate the Wright Brother's historic flight at Kitty Hawk. Yet during the Prussian battle against Paris in 1870, the French evacuated 160 wounded soldiers by hot air balloon out of the besieged city. Shortly after the inaugural flight of the airplane in 1903, senior military medical officers saw the potential for rapid evacuation of wounded soldiers from the front lines of battle. They formalized plans for an airplane ambulance in 1910 but the War Department rejected the proposal because there were safer methods of travel. Steam locomotive, ocean going ships, and horse drawn carriages were the preferred means of patient transport at that time.

The dismal safety record of the airplanes of this era brought an ironic twist to aeromedical transport history. Various flight training bases used standby aircraft to fly a flight surgeon to the crash site. This was the first use of a physician as an aeromedical crew member and was especially life saving for some early pilot pioneers.

There was little use of the airplane in the ambulance role during World War I. The bi-winged aircraft of this era did not have sufficient space to haul wounded servicemen and reliability of these machines was still an issue. The military experiment with an ambulance configuration as early as 1915. Later in the war, the army used a JN-4 "Jenny" for patient transport. A litter was placed inside the fuselage behind the pilot. One can only imagine the victim's thoughts while flying inside the dark hollow tube of this fabric biwinged airplane. Use of airplanes in this role was sporadic. A critic of air evacuation during WWI summarized the problems: "Are there not enough dead in France today without killing the wounded in airplanes?[1]"

There was rapid progress in both aircraft design and potential for air ambulance activity during the post war period. Transport airplanes were becoming larger and more reliable. Several litters could be loaded into the airplane to transport multiple casualties. The first true test of aeromedical evacuation occurred during France's campaign into North Africa in 1922. The French transported 3,000 wounded soldiers home from foreign battle fields over several months. The trip to France took only a few hours. Traditional transport using ships and ground ambulances would have taken several days.

The late 1930s saw rapid development and refinement of air evacuation. The Germans transported thousands of wounded Nazi soldiers over the Alps from Spain. The traditional use of ocean-going hospital ships took weeks yet the 1,600 mile flight to Germany was only eight to ten hours by air. The Germans changed the traditional practice of treating wounded at forward hospitals. They saw an advantage in rapidly transporting wounded soldiers to sophisticated hospitals better able to tend to the serious complications of battle. Military cargo planes brought supplies to the front lines and returned the wounded home. This was an efficient use of limited aerial resources The soldiers received better care and morale was improved. The approaching world war would test this concept.

World War II brought into clear focus the full value of aeromedical evacuation. From the attack on Pearl Harbor until VJ Day in 1945, approximately 1,360,000 wounded sailors and soldiers were transported home by air - with only forty six deaths occurring enroute.[2] Medevac activity reached a peak of 82,000 flights a month and a record of 4,700 patients were transported in a single day. General Eisenhower summed up the effectiveness of air transport: "We evacuated almost every one of our forward hospitals by air, and it has unquestionably saved hundreds of lives -thousands of lives."[3]

There was innovative use of several types of aircraft from transport category airplanes that bore the brunt of aeromedical evacuation, to gliders, and the first use of a helicopter for on-site pickup. In one instance, a helicopter flew a polio victim on a mechanical respirator from the jungles of Borneo to a distant hospital. The pilot flew the aircraft and managed the hand operated ventilator! The helicopter was not placed into general service, though. The routine use of helicopters for medical transport was still a few years in the future.

The Korean Conflict brought larger and faster airplanes into aeromedical flight duty. Pressurized transport planes began service and could accomodate sixty three litters. The cabin was heated or cooled depending on climate. The Korean conflict also saw the first widespread use of helicopters for transport of wounded soldiers. Two litter were attached to the aircraft's skids and soldiers were transported directly from the battlefield to rear trauma hospitals. The opening scene of the television series M*A*S*H, where nurses and physicians rush to attend incoming wounded transported by helicopter, has permanently seared this idea

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1 Guilford, F, and Soboroff, BJ (1947). Air evacuation: an historical review. Journal of Aviation Medicine, 18(12) p.601-616

2 Scheaffer, JN (1949). Deaths in air evacuation. ***Journal of Aviation Medicine***, **19** p.100-107

3 Grant, D. (1947). Air Evacuation Activities. ***Journal of Aviation Medicine***, **18**(4) p.177-183, 191

into our consciousness. In all, helicopters evacuated over 20,000 casualties during the Korean War.

The development of jets brought new and exciting possibilities for aeromedical evacuation. Initial use of a military jet air ambulance took place in October of 1961. This created the possibility of nonstop oceanic travel, and cut transport time from Europe to the U.S. from twenty to ten hours. In 1966 the C-141 Starlifter began transporting wounded directly home from Vietnam. The around-the-world trip took less than twenty-four hours. The military was finally realizing its dream of rapid stabilization and worldwide transport of wounded servicemen and women. Yet new problems began to emerge. The effects of long exposure to an aeromedical environment such as decreased humidity (and problems with airway dehydration), noise, vibration, pressure changes, and prolonged mild hypoxia had to be addressed.

After Vietnam, the military transferred medical evacuation to the Air Force Military Airlift Command. The primary jet, a C-9A Nightengale, serves as a dedicated hospital flying ward. It is capable of loading forty litter and forty ambulatory patients. The Nightengales have flown tens of thousands of patients over the past two decades. They have been described as ". . . a very effective tool in ensuring complete health care for seriously ill patients."[4]

The history of civilian aeromedical transport is a less conventional story. The Australians, with their vast and sparsely populated country saw the potential of an airplane ambulance. As early as 1912, a Presbyterian minister proposed the combination of airplanes and radios to bring medical help to the outback. The service began in 1918. Airplanes flew doctors into remote sites and airlifted patients to urban hospitals where they could receive sophisticated medical care. Over the years the service became the Royal Flying Doctor Service. Today, the RFDS flies 19,000 missions annually using over thirty aircraft.

The glaciers of Switzerland pose a remarkably different problem for aeromedical evacuation. Since 1946, the Swiss have used specially outfitted aircraft to rescue mountaineers off glaciers. This effort was organized during the 1950's and is called Swiss Air Rescue. The Swiss routinely used helicopters for medical transport in 1952. It replaced fixed-wing aircraft for mountain and glacier rescue. Swiss Air Rescue is also credited with the first dedicated civilian jet air ambulance when a Lear 24D began service in 1976. Today, nationwide telephone access Since 1960, over 41,000 missions have been flown without a single loss of life - a truly impressive record.

On a totally different continent, the South Africans operate air ambulance services under the Red Cross Society. Although the absolute number of missions pale to the Swiss and Australians, it is remarkable that this is a fully volunteer service. In its twenty year history, the service has completed 1,931 flights and transported 2,451 patients. This benevolent service is supported totally on community resources.

The United States does not enjoy such comprehensive and coordinated national air ambulance service. There is no national coordinating agency or unified coordinating system.

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4 Johnson, A., Cooper, J.T., & Ellegood, F.E. (1976). Five-year study of emergency aeromedical evacuation in the United States. ***Aviation, Space, and Environmental Medicine***, **47**(6) p.662-666

The evolution of civilian air ambulance transportation in the U.S. has been fragmentary. Fixed-wing air ambulance has been the domain of private air taxi operators until quite recently. Over the past few decades, over 500 charter companies have offered air ambulance transport in a range of charter services such as air cargo, air taxi, air photography, etc. There has been little regulation of air ambulance activities. A proposal by the Federal Aviation Administration [FAA] in 1977 would have guaranteed national standards and regulation for all air ambulance operators.[5] But the proposal was withdrawn after considerable negative attack from the air taxi industry. These proposed rules would have required an air ambulance operator to provide trained medical crew members and minimum equipment on all air ambulance flights. There is no current FAA requirement to provide medical equipment or trained medical attendants. Without Federal regulations, many states have passed legislation to regulate air ambulance activity. They may be ineffective, thought, since most fixed-wing flights cross state boundaries and states have minimal jurisdiction over interstate commerce.

During the late 1960s and early 70s state, federal, and military helicopter programs evolved in Ohio, Arizona, Maryland, California, and Pennsylvania. The Military Assistance to Safety and Traffic (MAST) program provided active or reserve military helicopters to civilian hospitals and government agencies for rescue and patient transport. The MAST program has flown over 16,000 patients since its inception in 1969. The United States Coast Guard also provides overwater rescue but does not provide overland aeromedical transfer except on rare occasions.

Hospital based programs, both fixed-wing and helicopter, have proliferated over the past fifteen years. These programs can bring sophisticated advanced life support equipment and trained personnel to rural community hospitals. They provide a high level of care and can move critically ill or injured patients to tertiary care hospitals. Some hospitals have purchased or leased dedicated aircraft. Other centers use multirole charter aircraft and quick change modules.

It is difficult to predict the future of air ambulance systems. There is currently a strong tendency for large referral hospitals to have a helicopter transport team and hospital based fixed-wing programs are also making a resurgence. Yet the continuing competition between sponsoring hospitals may created some duplication of effort resulting in a shake-out of the industry. Dedicated free standing fixed-wing providers are experiencing local and state regulation of their activities. Many smaller air taxi operators who provide air ambulance may be forced to comply with state air ambulance laws or cease medical transportation. Several volunteer programs have started around the county. The concept is very interesting since it emulates local volunteer rescue squads. This new direction in the industry may have a significant impact on the way patients will be transported by air in the future. The main problem with volunteers groups is maintaining funding and support. Aviation and medicine are two

notoriously expensive endeavors. These volunteer groups may see that it is difficult to sustain a quality service.

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5 Federal Aviation Administration (1977) ***Advanced Notice of Proposed Rulemaking, Air Ambulance Service***, No. 77-14 (42 FR 37825)

History of Flight Nursing

Specially trained registered nurses have been an inseparable part of aeromedical evacuation throughout its history. As early as 1930, civilian flight nurses organized as the Aerial Nurse Corps of America. The arrival of World War II would draw these early flight nurses to the military. Nurses became the primary medical crew members for the massive medical air evacuation during the war. The first military aeromedical evacuation squadrons formed in November of 1942 and nurses played a key role. In February of 1943 the first class dedicated to flight nursing was created. This four week course taught physiology, survival, sanitation, and problems of air medical evacuation. The army's chief flight surgeon, General David Grant, was enthusiastic about using nurses. On the first graduation he gave the following speech:

> *"Your graduation as the first class of nurses of the first organized course for air evacuation, marks the beginning of a new chapter in the history of nursing. For me, it's a realization of a dream which we, in the Armed Forces, have had for many years. For you, the duty contains great implications. You stand on the threshold of a new era in nursing. One will put into actual practice lessons that we have previously learned concerning the care of the sick and wounded during war. Surely the spirit of Florence Nightingale must glow with enthusiasm at the new worlds to conquer which have been opened to you."*

Flight nurses played a vital role in the transport of over one million servicemen during World War II. Since 1942 over 10,500 military flight nurses have continued in this tradition during peacetime and war. The origins of civilian flight nursing are vague. Several airlines such as Northwest used graduate nurses as flight attendants. The Aerial Nurse Corps of the 1930s disbanded due the war. Many of its members became the backbone of the flight nurse war effort. After the war, civilian aircraft began transporting sick and injured patients. Lee describes the efforts of a small group of nurses and physicians who formed the Medical Air Evac Association in 1960. Civilian flight nurse activity, though, is undocumented until the early 1970s.

The first organized use of civilian flight nurses coincided with the start-up of the first civilian hospital based helicopter program. In 1972, St. Anthony's Hospital of Denver Colorado began twenty-four hour dedicated helicopter air ambulance service. Since then, helicopter flight nursing has captured the imagination of the profession. Since 1972, over 140 helicopter programs have started. To meet the growing need of this specialty group, the National Flight Nurses Association organized in 1981. Its membership continues to grow.

What does the future hold? Registered nurses will continue to play a vital role in aeromedical evacuation alongside other team members. Helicopter flight nursing will continue to expand the scope of practice of registered nurses and military flight nursing will continue to make world wide military evacuation possible. Other professionals such as paramedics, EMT's, and respiratory therapists have joined the aeromedical team and have made a substantial impact on patient care. It is certain that these professionals will continue to play a dominant role in aeromedical transport.

Aircraft Used for Aeromedical Evacuation

Two broad categories of aircraft are used for air transportation: helicopters, or rotary-wing aircraft; and conventional airplanes known as fixed-wing aircraft. There are advantages and disadvantages to both types. Helicopters are generally slower than their fixed-wing counterparts. There is usually less cabin space that limits patient access in some circumstances. Yet a helicopter can land vertically into a small area, such as a parking lot, but an airplane must land at an airport. This trade-off gives the helicopter the ability to provide direct hospital to hospital transfer. On longer flights of over 150 miles, conventional airplanes excel because of speed and ability to climb above weather and mountainous terrain.

Fixed-wing aircraft

Conventional propeller and jet aircraft have been used for patient evacuation. These airplanes can be divided into several categories:

1. Pressurized vs. nonpressurized;
2. Single vs. multi-engined;
3. Piston, turboprop, or jet aircraft and;
4. Short, medium, or long range aircraft.

Table 1: Aircraft Comparison

Aircraft	Description	Speed [MPH]	Minimum Runway[6]
Piper Seneca	Nonpressurized twin pistonprop	165	2,400
Beech Baron	Nonpressurized twin pistonprop	195	3,500
Piper Navajo	Nonpressurized twin pistonprop	180	3,500
Cessna 340	Pressurized piston prop	175	3,500
Cessna 414	Pressurized piston prop	175	3,500
Beech King Air 90	Turboprop	225	4,000
Piper Cheyenne	Turboprop	230	4,000
Mitsibushi MU2	Turboprop	275	4,000
Cessna Conquest I	Turboprop	230	4,000

[6] Approximate balanced field length varies by pressure altitude and temperature, e.g. hot and high altitude requires significantly longer balanced field runway lengths

Cessna Conquest II	Turboprop	275	4,000
Cessna Citation	Jet	330	4,000
Lear 20 Series	Jet	440	5,000
Lear 30 Series	Jet	440	4,500

All conventional airplanes must land at an airport so a ground ambulance is needed to transfer the patient to/from the accepting health care facility (or home). Yet for longer distances, especially over 150 miles, fixed-wing aircraft can cover a greater distance than a helicopter. This 150-200 mile range represents the decision point for using helicopters vs. airplanes. Yet there are no absolute contraindications for using fixed-wing less than 150 miles or a helicopter for greater distances. There is a point where time and costs favor the fixed-wing transport.

The debate over using pressurized or nonpressurized airplanes is ongoing. The preferred aircraft is a pressurized turboprop or jet. Range, speed, and size are greater than a nonpressurized aircraft. But nonpressurized airplanes are often cheaper to operate and can sometimes land in smaller airports. For example, the Piper Seneca can land/takeoff in as little as 2,400 feet of runway. This is much shorter than other aircraft. The tradeoff in using a nonpressurized airplane is the medical condition of the patient. Will there be serious side effects if a patient is exposed to a high altitude? The other consideration is speed. Most nonpressurzed airplanes are slower than turboprops and jets. The speed vs. distance question is significant for long distance transports. There are no real contraindications to in-flight transport times up to eight or ten hours. The argument is mainly what is reasonable. If a jet is available it could reduce a ten hour trip in a Piper Seneca to under four hours.

Because nonpressurized aircraft must fly at lower altitudes, turbulence is more of a problem. Convective turbulence from uneven ground heating can occur as high as 8,000 to 9,000 feet in the summer. This can cause a very rough ride for passengers and crew. Noise levels also tend to be higher in nonpressurized airplanes and this can lead to increased fatigue and communication difficulty. Interior cabin space is also an issue. Light twins such as the Piper Seneca and Beech Baron have very restricted interior cabin space. This may be an important consideration for providing patient care. Often, these less costly airplanes may restrict access to the patient and make in-flight care difficult.

Pressurization alleviates some problems of high altitude flight but does not eliminate them entirely. Cabin pressures range from sea level to 8.000 feet with normal cruise altitudes. The pressurization system draws air from the outside environment and compresses it within the sealed cabin. Air within the cabin in vented to the external environment at a much slower rate causing a pressure differential. This differential is dependent on the aircraft design, patency of pressure seals [such as the cabin door], and the cruising altitude of the airplane. All pressurized planes will maintain a sea level cabin to a certain altitude, then rise slowly. At maximum cabin pressurization, the cabin atmosphere will rise in altitude with further increases in aircraft altitude. For example, a turboprop may have an 8,000 foot cabin at 21,000 feet cruising altitude. If the turboprop climbs to 23,000 feet then the cabin would be pressurized to 10,000 feet. If you need to restrict a patient to a certain cabin altitude (such as 4,000 feet) then the aircraft will fly at a much lower cruising altitude. For turboprops and jets this will greatly increase fuel burn and cost of operation. It also decreases airspeed and lengthens the trip. This decrease in performance must be evaluated. Yet the flexibility of being able to "pump up the cabin" is a real advantage for patient care.

Another disadvantage of pressurization is low humidity at high altitude. This is more of a problem in jet aircraft than with turboprops because the ambient humidity of the atmosphere is related to altitude. At high altitudes, cabin humidity can be less than 5% and can cause dehydration or other humidity related problems. Control of cabin temperature is also a problem. Since air temperature is usually below freezing above 18,000 feet (and may drop to -40 degrees C or more above 30,000 feet) the cabin must be warmed. Frost and ice can form on door hinges which may cause sticking on the ground. Frost can also form on the interior bulkhead so watch that an unconscious patient does not lie against the cabin - frostbite can occur.

The use of pressurized airplanes is a trade-off. On one hand, you have greater latitude and flexibility in flying with patients who may have serious side effects when exposed to high altitudes. On the other hand, pressurized airplanes are usually more costly to operate and may not be able to land at small airports.

Rotor-wing aircraft

Helicopters are hailed for their life saving ability. They combine exceptionally trained medical crews, sophisticated advanced life support equipment, and rapid transport. This capability can reduce mortality and morbidity for critically injured patients.

The helicopter an advantage over fixed-wing aircraft. It can land and takeoff vertically therefore a helicopter can proceed directly to a hospital or accident site. Ground transport from airport to hospital is rarely needed. Helicopters can generally travel 250-400 miles without refueling. This gives them an effective nonrefuel radius of 100-150 miles from their base hospital. The helicopter is not a panacea, though. Because of its small size it has much more restrictions on internal cabin space than typical fixed-wing cabins. This can make administering advanced life support particularly difficult. Procedures such as starting intravenous lines or placing endotracheal tubes must usually be completed before loading the patient into the aircraft.

The helicopter is not pressurized but this is usually not a problem since it will fly at low altitudes except in mountainous terrain. Therefore the effects of altitude are usually least. One problem that is significant in helicopters is noise. Communication without headsets and intercom is nearly impossible. Listening for breath, heart, and abdominal sounds is also not feasible.

Weather can be formidable. A helicopter will usually fly "under the weather" at low altitudes. This is called using Visual Flight Rules [VFR] which means that the pilot must maintain visual contact with the ground and horizon and cannot fly through clouds or in poor visibility. Fixed-wing aircraft can fly VFR or fly on instrument flight plans [IFR] and where they are tracked on radar by air traffic control. IFR aircraft will land at airports with precision or nonprecision electronic guidance. VFR flight exposes the rotor-wing crews [and fixed-wing crews not on IFR] to obstructions and terrain. In poor weather or at night, these may prove to be fatal obstacles. The debate over using helicopters at low altitude in marginal weather vs. fixed-wing aircraft on instrument flight plans is ongoing. Helicopters have proven to be effective vehicles for saving lives. Yet flying a helicopter to a mountainous accident scene at night in bad weather may be heroic or foolhardy depending on your perspective.

Flight Physiology

Aircraft travel through the atmosphere at varying altitudes from sea level to above 40,000 feet. The different layers of the atmosphere and its characteristics must be understood to appreciate the environment which we transfer patients. Changes in the external environment will have aeromedical consequences within the aircraft used for the transfer.

Layers of the Atmosphere

The atmosphere is a mixture of gasses - mainly oxygen, nitrogen, carbon dioxide, and water vapor, with a small amount of trace elements [helium, hydrogen, krypton, neon, and xenon]. As a practical matter, air can be regarded as having a mixture of seventy nine per cent nitrogen, twenty per cent oxygen, and one percent other gasses. This gaseous layer of air has several properties, namely: pressure [density], temperature, and humidity. These properties interact and change with changes in altitude.

The atmosphere can be roughly divided into the inner atmosphere and the outer atmosphere [or exosphere] at 600 miles. The inner atmosphere divides into three categories:

Troposphere

This is the layer closest to the Earth. It extends from sea level to a varying height of 20,000 to 65,000 feet. Nearly all aircraft fly within this layer.

Stratosphere

The next layer begins at the edge of the troposphere and extends to fifty miles above the Earth. Temperature in this region is stable at fifty five degrees Centigrade due to the chemical reaction of ozone. This is also the layer of the atmosphere where the jet stream forms. Only high performance military aircraft can operate at this altitude.

Thermosphere

The thermosphere, also known as the ionosphere, extends beyond the stratosphere from fifty to four hundred thirty miles above the earth. The ionosphere's charge particles deflect most radio waves and provide long range communication [short wave radio].

Aeromedical evacuation occurs at altitudes below 50,000 feet. Therefore the troposphere is the only layer of interest. Every flight team member should understand the hostile environment that surrounds the aircraft. No airplane is immune from mechanical failure. A shirtsleeve environment at 41,000 feet in a Lear jet could suddenly become quite lethal during a rapid decompression.

The following characteristics of the thermosphere are associated with changes in altitude:

Air pressure generally decreases at a rate of 1.0 inch per square foot (PSI) per 1,000 feet. This produces a decrease in the total atmospheric pressure as well as the partial pressures of oxygen and other gasses. The percentage of gas remains the same. [i.e. oxygen percentage remains roughly twenty percent of the total mixture of gasses]. Weather patterns such as high and low pressure systems make the pressure at a particular altitude variable.

Temperature decreases at a rate of 3.5 degrees F (or 2.0 degrees C) per 1,000 feet known as the lapse rate. This also is not always uniform due to weather phenomena and moisture content of the atmosphere. At 18,000 feet temperatures are usually below freezing. Ambient humidity decreases with altitude.

In later chapters we will see how these physical properties of the atmosphere will have physiological effects on the human body. Please keep in mind that even minor problems such as dehydration due to low ambient humidity can create problems on long trip.

Gas Laws

There are certain physical laws that determine the behavior of gasses. They have an important bearing in understanding the mechanisms of changes in altitude and how they affect man.

Boyle's Law

This law determines how pressure and volume of a gas interact. These two properties are inversely related, that is, as pressure is decreased the volume of a particular sample of gas will increase. At 18,000 feet, the atmospheric pressure would be half that of sea level and the volume of a particular gas would double. This can be represented by the following equation:

$V = 1/P$ [temperature constant]

This is a simplified formula and does not consider the effects of water vapor and other complex physical properties. This law has practical significance in the aeromedical environment. As an aircraft takes off and climbs to altitude, atmospheric pressure will fall. Correspondingly, the volume of a particular sample of gas will expand. Any air trapped in a body cavity will expand as the airplane gains altitude.

Pressurized cabins will help to alleviate this problem to a point. Yet most pressurized aircraft, jet and turboprop planes alike, will not usually fly with a sea level cabin. To maintain reasonable performance, speed, and fuel consumption, pressurized aircraft will generally fly at a cruising altitude that maintains a cabin altitude between 2,000 and 6,000 feet. In nonpressurized aircraft, the cabin pressure will be equal to the outside pressure.

Dalton's Law

Since the atmosphere is a mixture of gasses, each individual gas will exert a pressure that is a portion of the total pressure exerted by the gas mixture. Known as a partial pressure, the formula can be represented as:

$$P\ total = P_1 + P_2 + P_3 \ldots . P_n$$

Where: P total is the total pressure of the gas mixture. P_1, P_2, etc. are the partial pressures of the individual gasses [such as oxygen and nitrogen].

The partial pressure of an individual gas can be determined by multiplying its percentage in the gas mixture by the total pressure of the gas. For example, the standard pressure of the atmosphere at sea level is 760 mm Hg and the percentage of oxygen is twenty per cent. At sea level the partial pressure of oxygen would be:

760 x 0.20 = 152.0 mm Hg

Nitrogen would be:

760 x 0.79 = 600.4 mm Hg

760.0 mm Hg total

At 10,000 feet the standard pressure would be 522 mm Hg and the partial pressure of oxygen would be:

522 x 0.20 = 104.4 mm Hg [a 31% decrease in available oxygen from sea level]

The aeromedical flight crew must take this phenomena into account. Patients with a decrease in oxygenation before flight, for example pneumonia or pulmonary edema will be at high risk. The decrease in ambient oxygen tension will further exacerbate the existing hypoxia. Supplemental oxygen must be given to compensate for travel at higher altitudes. Consider transporting these patients in a pressurized aircraft and limiting their exposure to higher altitudes.

Henry's Law

The behavior of gasses when dissolved in a liquid medium is different from a free volume. When a gas is dissolved in solution at equilibrium and is not chemically bond, its partial pressure is equal to the pressure outside the liquid. If the pressure outside the liquid changes, the solubility of the dissolved gas in the liquid medium changes proportionately.

This pressure change could possibly liberate some dissolved Nitrogen gas especially if the pressure gradient is severe and rapid. This is known as dysbarism.

At the normal operating cabin altitudes of an air ambulance, this will have little significance. If a rapid decompression occurs in a jet operating at 41,000 feet, the sudden and severe pressure changes could possibly cause dysbarism. Nitrogen gas liberated from tissue occurs at different rates. There are three classifications: fast phase tissue, such as blood, liberate nitrogen readily; medium phase tissue like muscle release nitrogen less rapidly; and slow phase tissue such as fat are negligible. [Lowery]. Nitrogen bubbles form in the blood stream and can be trapped in the lung micro circulation causing a feeling of suffocation know as "the chokes". Nitrogen trapped in the joints are called "the bends".

Gas Diffusion

Gas mixtures will cross a permeable or semipermeable membrane to reach equilibrium. The rate of this diffusion is related to the surface area of the medium, its permeability, solubility, and the differences in partial pressures between the two gasses. This concept explains how oxygen and carbon dioxide are transported from the lungs into the blood. Differences in gas partial pressures exist between the alveoli and capillary blood. The partial pressure of oxygen in the alveoli is approximately 100 mm. The partial pressure of oxygen bound to the hemoglobin molecule is approximately 40 mm [75% saturation] for normal, healthy individuals. This causes a pressure gradient and oxygen diffuses across the lung membrane from the alveoli to the desaturated hemoglobin molecule on the red blood cell. Any restriction to this diffusion process, such as pulmonary fibrosis, pulmonary edema, or infectious processes such as pneumonia, can impede the diffusion of oxygen across the cell membrane.

This diffusion principle is also responsible for cellular respiration [oxygenation of the individual tissues and cells of the body]. A pressure gradient exists between the oxygenated red blood cell and the individual cell. Oxygen migrates across the capillary membrane into the individual cell. Any process that impedes the oxygenation of individual cells can cause serious if not fatal consequences. tympanic membrane or middle ear is also possible when exposed to atmospheric pressure changes. Absolute risk from noise varies between type of aircraft. The most serious potential for hearing damage occurs in helicopters, followed by nonpressurized fixed-wing aircraft, and finally pressurized aircraft Prolonged exposure to even moderate noise may produce fatigue, headache and motion sickness. Hearing protection is strongly recommended for all crew members.

Infants present a special problem with aircraft noise. Douek and associates and Blennow et al. determined that the immature ear of a preterm infant is at higher risk for damage to the sensory cells of the cochlea. A study of neonatal transport showed that maximum noise and vibration exposure occurred in helicopter transport, then ground ambulance, followed by fixed-wing aircraft. All infants transported in isolettes should have hearing protection throughout the transfer.

Noise contamination also generates a significant clinical problem. The flight crew must rely on stethoscopes to auscultate blood pressures and to listen for lung ventilation, cardiac sounds, and abdominal activity. This is nearly impossible in a noisy cabin environment. At best, blood pressure may be measured by palpation or by electronic means. Listening to lung, heart, or abdominal sounds, as a pragmatic matter, is not feasible in the noisy cabin. It is also difficult to communicate with other persons in the aircraft.

Aircraft Vibration

All aircraft produce vibrations. This is related to air flow over wing surfaces, fuselage, rotor blades, and propellers. There are several problems associate with prolonged exposure to low frequency vibration. These include: changes in mean arterial blood pressure; pulmonary edema; fall in body temperature; and a lowering of the seizure threshold. Although the true effects of vibration on patients in an aeromedical environment are unclear, vibration interacts with the other stresses of flight and has an additive effect.

There are some practical issues concerning vibration during aeromedical evacuation. Any contact between the patient's skin or boney prominences and the aircraft bulkhead, stretcher supports, or restrains may cause skin breakdown or nerve palsy. This is especially dangerous in unconscious patients since they cannot express discomfort or pain. Stretcher straps can be troublesome during turbulence because a snug fit is needed for safety. Yet vibration may cause skin tears or abrasions. Evaluate strap security and skin integrity often during the flight and change the patient's position frequently, if possible, to prevent complications due to aircraft vibration.

Vibration also hinder the operation of medical equipment. For example, cardiac monitors are especially sensitive to artifact induced by aircraft vibration. Other delicate equipment such as oxygen analyzers may be damaged. Vibration can cause an unsecured piece of equipment to fall off a stretcher or seat. Take care to secure all equipment in the cabin and never leave any item loose on the stretcher.

Fatigue

Fatigue is the end result or the cumulative effects of all stresses of flight. Additional factors such as obesity and poor physical conditioning tend to increase the degree of fatigue experienced. Smokers and those who intake alcohol the night before a flight will be more sensitive to the effects of mild hypoxia. Constant vibration and noise continually plague passengers, patients, and crew members. Time zone changes will disturb normal Circadian rhythms and may augment any of the above phenomena.

Fatigue will impact both the patient and crew. From an operational standpoint, the following characteristics of fatigue will encroach upon crew performance.

Table 1. Effects of Fatigue

- Increased irritability;
- Increased anxiety;
- Increased reaction time;

- Decreased ability to concentrate;
- Increased awareness of physical discomfort;
- Increased blood lactic acid level;
- Increased catecholamines levels.

For the patient, these stressors may intensify discomfort at the very least. Increases in circulating catecholamines may produce serious physiological consequences such as cardiac dysrhythmia. For the medical crew, decreases in performance may impinge on patient care. For the pilot, errors in judgment may be fatal. It cannot be overstated that fatigue must be avoided.

Aerospace Medicine

The discussion on the stresses of flight gives an incomplete picture of aeromedical transportation. Several other concepts must be addressed.

Safety in an Aeromedical Environment

The airport and aircraft is a new and dynamic environment for many people. Common sense must prevail in order to ensure the safety of all crew members, passengers, and patients. A few simple measures will help to prevent accidents and incidents.

- Always walk away from and around parked airplanes. Be specially watchful of taxiing airplanes, propellers and jet blast. Never walk under the wing of an airplane and especially avoid the propellers even if the aircraft is unoccupied. Never run, always walk on the ramp.
- If you must walk around an aircraft with engines running, always stay in clear view of the pilot and pass at least twenty five to thirty feet in front. Stay well clear of jet blast - maintain at least three hundred feet behind jet engines and stay clear of jet intakes.
- No smoking within fifty feet of the ramp. A burning cigarette can ignite highly flammable aviation fuel.
- Use extra caution when working with ground ambulances on the flight line. It is very easy to back an ambulance into a wing or engine. Adhere to a ten feet circle of safety around the aircraft for all ground vehicles. Instruct the driver to leave the keys in the ignition. Avoid laying objects on the wings [such as clipboards or flight bags] to prevent damage to vital control surfaces. Use caution when loading the patient because of weight limits on the door or stairs.

- Never leave a patient unattended. If you must use the bathroom facilities during a fuel stop, have the pilot or copilot stay with the patient. During refuel with a patient on board, have ground fire equipment immediately available. Air Traffic Control will be able to arrange for a standby crash crew at the refueling site if one is available. If a crash crew is not available on the airport, have portable fire extinguishers at ready during all refueling procedures. If possible, offload passengers and patients during refueling avoid exposure to toxic fumes.
- KNOW YOUR AIRCRAFT. There is little time during an emergency to learn how to use an emergency exit or aircraft oxygen. Take time during preflight to review emergency procedures with other crew members. Check safety and emergency equipment before starting on a mission.

Turbulence

Turbulence can occur at any altitude yet flights below 5,000 feet are more likely to experience a "bumpy ride". This is particularly true during the summer months when uneven heating of the ground will produce unstable air. Certain cloud formations such as the billowing cumulus types indicate unstable air. Even more ominous are large cumulonimbus thunder clouds that are extremely dangerous and can produce turbulence over a wide area. Any time the airplane goes through clouds expect some amount of turbulence. The area just above and just below cloud formations can be particularly rough. Another type of turbulence is called clear air turbulence [CAT]. It can occur in clear weather and cause severe altitude drops of several hundred feet.

Because turbulence can occur at any point during the flight, always keep seat belts secured. Clear air turbulence can be especially unexpected and violent. Injury is possible to any unprotected passenger or crew member. If you must remove your seatbelt, keep one hand free to brace yourself against the cabin or seat. When finished, rebuckle and remained buckled. Passengers [and crew] also tend to become air sick during high motion flights. Keep an air sick bag handy. Small plastic garbage bags are quite versatile. Not only do they make potential air sick bags but they can be used for garbage containers to help keep the cabin uncluttered. Never leave equipment unsecured. Any loose equipment in the cabin such as an oxygen bottle has the potential for becoming a missile. Seemingly innocuous items such as a metal clipboard or scissors can cause injury in turbulent air.

Acceleration Forces

Acceleration is the rate of change of velocity with time and occurs when the speed or direction of motion of a body alters. The speed of aeromedical transport vehicles, which can reach several hundred miles per hour, can create significant velocities during flight, especially during takeoff and landing. This force is commonly call gravity or G forces. When an acceleration (or deceleration) force exerts pressure twice the strength of gravity [2G's], a person will feel as though he is twice his weight. Acceleration acts on body fluids causing their redistribution. Unprotected individuals who experience a force of 5 to 6 G's will usually black out due to loss of blood flow to the brain. Yet G forces of this magnitude will rarely be experienced in an aeromedical environment except during an emergency.

Acceleration forces will be most significant during takeoff and landing. During takeoff, a patient positioned with his head toward the front of the aircraft will experience venous pooling in the lower extremities. Likewise, a patient who is supine with his head positioned toward the rear will have blood redistribution to his head. Reddick experimented with acceleration forces in dogs. During takeoff, he found that there was a 25 to 30% increase in saggital sinus [intercranial] pressure. This may have significant implications in patients with brain injuries, cerebral edema, or eye trauma. Ideally, these patients should lie with their heads toward the front of the aircraft. Cardiac patients may be at risk from acceleration forces during takeoff. Blood redistribution to the lower extremities from head forward positions may cause dizziness or possibly hypotension. Slow venous return can affect cardiac output. It may be advantageous to place these patient's feet first in the aircraft and raise their heads to a semifowler's position for takeoff.

Landings will present the opposite problem since deceleration forces will be encountered. Yet deceleration forces during landing are much more mild than the acceleration forces of takeoff. It would be impractical in most aircraft used for air ambulances purposes to reposition the patient for landing.

Air Sickness

Air sickness during flight can be problematic and can happen to everyone. Contributing factors include:

- Psychosomatic disturbances such as loss of familiar surroundings, apprehension concerning safety in flight, and emotional stress;
- Fatigue;
- Overindulgence in alcoholic beverages or dietary indiscretion before flight. An empty stomach or hypoglycemia can also enhance the potential for motion sickness;
- Position in aircraft: in large aircraft, the rear section will have the greatest amount of motion. Facing rearward during flight may predispose a patient (or passenger) to motion sickness;
- Weather conditions: turbulence is a major factor in producing motion sickness. Any flight through clouds or below 5,000 feet is likely to experience turbulence.
- Inadequate ventilation, as well as excessive heat, alone or in combination will accelerate discomfort;
- Fumes and odors (especially jet fuel);
- Increased altitude and hypoxia exacerbate all of the above problems.

Symptoms are progressive and include the following: apathy, headache, stomach awareness, pallor, perspiration, nausea, vomiting, and prostration. For patients with a prior history or predisposition to motion sickness, premedication with Promethazine [Phenergan]

12 - 25 mg IM two hours before flight is recommended. The flight crew should not take any antiemetic or antimotion drug except under the advice of the medical director. If the patient experiences motion sickness during a flight the medical crew should take the following action:

- At the first signs of motion sickness: have person relax; decrease cabin temperature; loosen clothing; open vents to blow air directly on the face; moisten forehead and face with wet washcloth or premoistened towlettes; lie person flat or in a position of comfort; have person fix gaze on an object inside the aircraft and do not look outside the aircraft; close curtains or window shades to darken the interior; if stomach awareness has not occurred have something light to eat such as crackers but avoid carbonated beverages.
- If vomiting occurs and persists, an antiemetic such as Phenergan or Tigan may be indicated. Air sickness is usually self limiting and causes only discomfort. Bet in patients who may be in danger from aspiration, such as a person with jaw wires, an antiemetic should be administered prior to vomiting.
- Have suction readily available and have the patient vomit into a plastic garbage bag.

Ear/Sinus Blocks

A small amount of air is present in the middle ear that is sensitive to changes in pressure. As the ambient pressure declines on ascent, air in the middle ear expands and is passed through the Eustachian tube to the posterior nasal passageways. On descent, ambient barometric pressure increases and the volume of air in the middle ear will shrink. This pressure differential must again be equalized through the Eustachian tube. Yet the tube more readily passes air out of the middle ear. This creates a one way flutter valve effect. This is also the reason ear blocks are much more common during descent. Pressure differentials across the tympanic membrane may at first produce pain but as the pressure differential increases, hemorrhage and perforation can occur. This is called barotrauma.

Changing pressure affects the paranasal sinuses in a similar way. Air volume in the sinuses will increase on ascent and decrease on descent. Aerosinusitis occurs when pressure differentials between the sinuses and nasal pharynx cause pain. Frontal aerosinusitis is the most common form of sinus barotrauma and will produce pain over the forehead on either side. Maxillary aerosinusitis causes pain over the nose and cheekbone of the effected sinus and is related to unequal pressure in the maxillary sinus.

Treat sinus block and ear block as follows:

1. Ask all patients or passengers whether they have had previous problems with their ears or sinuses during flight. Advise the pilot if there is a positive history so that he may plan for a slower descent from altitude. This is more of a problem in nonpressurized airplanes.
2. Awake all patients and passengers before beginning descent. During sleep, the normal swallowing reflex is diminished and predisposes a person ear block.
3. Remove ear plugs or hearing aids during ascent and descent.

4. If sudden ear or sinus pain develops, have the person yawn, swallow or cough. Chewing gum on descent may help prevent problems for passengers and crew members. Do not chew gum on ascent because air is ingested into the stomach potentially causing abdominal discomfort or distention.
5. If pain persists have the person close his/her mouth, pinch their nose and blow gently.
6. If pain persists, inform the pilot of the problem. If possible, he/she will alter the aircraft's altitude.
7. Neosynephrine nasal spray can be used for persistent pain unrelieved by the above maneuvers. Neosynephrine should not be given to persons with known sensitivities or allergies to the drug.
8. For unconscious patients who become restless or combative during descent, consider an ear or sinus block. Suctioning the patient may elicit a cough reflex. The jaw may also be exercised or moved if not contraindicated. If this does not relieve the problem, Neosynephrine may be administered. Consider restricting unconscious patients to a cabin altitude of 4,000 feet to avoid this problem.
9. In extreme cases, the flight crew may ambu-bag the patient in an attempt to rectify the problem. Place the mask firmly over the face and use quick inflations. Air forced into the nasopharynx may open a blocked Eustachian tube or sinus. Air may be forced into the stomach during the procedure. This can cause abdominal distention, pain and possible vomiting. Therefore this procedure should only be used as a final measure.
10. For infants, have a pacifier or bottle available. Wake the infant before descent and if he/she suddenly becomes irritable and cries, consider an ear block. The pacifier or bottle should rectify the problem in short order. Neosynephrine is generally contraindicated in pediatric patients

Systems Review & Aeromedical Concerns

We have covered theory on the stresses of flight and altitude physiology. This chapter will turn its attention toward practical applications of theory in the transport environment and explore the effects of altitude on different organ systems. What are the implication of transporting a patient in an airplane with a specific problem, for example a head injury or pneumonia? What are the multiple effects of altitude on different physiological systems? What is different about taking care of a small child in the air as opposed to taking care of that same child in a hospital?

These questions will be addressed. It is important to note that each body system is not isolated but interacts with other systems. For example, hypoxia caused by a combination of decreased partial pressures of oxygen and pneumonia will cause changes in sensorium due to decreased oxygenation of brain tissue. Throughout the following discussion of the aeromedical implications of flight, consider the total picture and the interaction of the stresses of flight on all body systems.

Neuro

The effects of altitude present two major problems: hypoxia, and changes in pressure [Boyle's Law]. These can have profound implications for the central nervous system. The cranium is a rigid vault and any air trapped within the skull is subject to expansion at altitude. Even small changes in altitude may hasten dangerous problems due to compression of brain tissue by expanding intercranial air. Patients with frontal or basilar skull fractures are at particular risk since these injuries can produce air within the skull. Emergency transport of these patients will require a pressurized aircraft with as little change in altitude as possible. Alternative transport by ground may be necessary when a pressurized aircraft is not available. Patients who have had an air pneumoencephalogram, although uncommon in contemporary clinical practice, are also at risk and present a relative contraindication to aeromedical evacuation. Ideally, any patient with trapped intercranial or spinal air should not be transported until the air is absorbed. If there is an urgent need to transport such a patient, consider using a pressurized aircraft and restrict cabin altitude. There are no real guidelines for a safe altitude in such an instance. Theoretically any increase in altitude could cause problems.

Consider transporting these patients with minimal increase in altitude. The ideal choice is to fly with a sea level cabin. Hypoxia is another aspect of aeromedical transport that will affect the central nervous system. The brain has a very complex regulatory mechanism to ensure adequate perhaps of blood to this vital tissue. Yet autos cannot compensate for hypoxia due to the decrease in partial pressure of ambient oxygen. Early hypoxia will cause changes in sensor and mediation. It will eventually lead to motor dyspepsia and unconsciousness. Elderly patients are more sensitive to hypoxia because atherosclerosis may diminish cerebral perhaps. Exposure to altitude may cause mental status changes in the elderly patient who was alert and oriented on the ground. If a patient becomes confused at night, he/she may be predisposed to developing symptoms during flight. Supplemental oxygen may be of benefit if hypoxia presents a problem with sensorium. Yet be cautious in using oxygen with chronic lung disease patients. The added oxygen may diminish their breathing drive causing hypercapnia [increase in arterial CO2 level] and possible respiratory arrest. Oxygen is always indicated for emergency transport of acute head injuries or other critical central nervous system pathology.

We addressed acceleration forces in a previous chapter. During takeoff and landing these forces can increase or decrease blood flow to the brain. The changes in cerebral perfusion are position dependent. That is, if a patient is lying with his head toward the rear of the plane during takeoff, blood will engorge in the skull. This will cause a transient rise in intercranial pressure [ICP]. Patients who are sensitive to these transient but significant rises in ICP may be at risk. For example, patients who already has a rise in ICP due to head injury, tumor, encephalopathy, or hydrocephalus, may be in danger by placing their head toward the rear of the plane during takeoff. There is also a theoretical argument for changing this patient's position for landing [i.e. placing them head rearward]. Yet this may be impractical for many if not most aeromedical transport vehicles due to space limitations. The deceleration forces of landing are much more mild that the acceleration forces of takeoff and should not present a real problem. Therefore, all patients with central nervous system pathology should be transported with their head forward.

Seizures are possible in the aeromedical environment and can be aggravated by hypoxia, hyperventilation, fatigue, stress, or harmonic vibrations from the propellers. Patients with past histories of seizures should be instructed not to look at the propellers or to watch the strobe lights on the exterior of the plane. Patients with uncontrolled seizures should be carefully evaluated and avoid aeromedical transfer if more appropriate transport alternatives exist. Uncontrolled seizures present a real danger. They must be stabilized before air evacuation. When air travel is mandatory for patients with a high probability for seizure, supplemental oxygen should be given throughout the flight. Airway and suction equipment must be readily available. Always establish an intravenous line to administer antiseizure medicines.

Patients with spinal injuries need special consideration. Patients in cervical traction with tongs are difficult to accommodate because of the problem of maintaining traction. Rigid immobilization of spinal injuries on a back board may be extremely uncomfortable during air transfer but may be mandatory for preventing further spinal cord injury. Additional aggravation of the spinal injury during onloading or offloading is possible and turbulence, even with superior immobilization may be a problem.

Yet patients with spinal injuries can be safely transported by air. Acute spinal fractures must be effectively immobilized. The key objective is to prevent further injury. Immobilization of cervical injuries requires a rigid collar to prevent any movement of the neck. A back board may be needed but this can be quite uncomfortable as already indicated. A scoop stretcher may provide a reasonable alternative if the injury can be stabilized. It is also much easier to load a patient on a scoop stretcher into a typical airplane used as an air ambulance.

Transport of older or healing spinal injuries provides some greater latitude. In these instances, backboards are usually not suggested. Patients may be transported in a halo vest, a rigid cervical collar and head fixation device. Bring along extra pillows to provide comfort and positioning for the trip. Patients transported in a halo apparatus should have a wrench attached to the vest. The halo jacket may have to be dismantled if rapid extrication is needed after a forced landing. Other patients with neck or back injuries may be transported on an eggcrate mattress. This foam mattress is an excellent cushion for long and even short trips. The patient can be transported directly from hospital bed to hospital bed on the eggcrate and loading is not usually hampered. Consider using an eggcrate for all patients.

Use extra care when loading patients with spinal injuries. Avoid unusual twisting or sudden drops. This may be difficult in aircraft with narrow doors, though. Do not manipulate the neck or spine. There is no real contraindication to flight in nonpressurized airplanes. During the summer months, turbulence may be a problem because of the lower cruising altitude of these aircraft. Log roll the patient to remove sheets. Instruct hospital or ambulance attendants about loading procedures and talk to the patient before and throughout the transfer.

Eyes, Ears, Nose and Throat [EENT]

The retina is the most oxygen sensitive tissue in the body. This is the primary reason visual changes may be the first signs of hypoxia. All patients with eye disease should be evaluated for flight. Patients with glaucoma are not appreciably affected by altitudes under 10,000 feet yet patients with retinopathy, retinal detachment, or recent intraocular surgery may have problems at altitude. (Voss, 1983). Intraocular gas will expand with changes in altitude and hypoxia will cause dilation of retinal vessels and possible rebleeding of previous retinal hemorrhage [Johnson - Surgical]. Rapid decompression may be particularly harmful to patients with eye disease. Consider moving patients with acute penetrating eye injuries by ground. If this is not feasible attempt to maintain minimal altitude change. The medical crew should observe for increasing pain, blurring, loss of vision, visible hemorrhage, protrusion of the globe, changes in pupil size or shape, or photophobia. Narcotics which produce pupil constriction should not be given except under the advice of an opthamologist.

Corneal drying is another potential problem due to low ambient humidity. Contact lens wearers are at risk and contacts should be removed for long flights or moisturizing agents administrated. A pair of eyeglasses should be brought by crew members who wear contact. For unconscious patients, the eyes should be moistened with an opthalmic agent or with sterile saline.

The ostia of the sinuses and Eustachian tubes are less patent with infection, allergies, or polyps. Patients or air crew members who experience any of these may be at increased risk for otitic or sinus barotrauma. Nasal decongestants or vasoconstricting agents such as Neosynephrine should be used as appropriate. Many over the counter cold remedies, especially antihistamines, will increase the effects of hypoxia and can produce drowsiness. These should be avoided by the flight crew. Ideally, a flight should be delayed if short term ENT problems arise. Unconscious patients will be unable to clear their ears and sinuses. Because of the risk of otitic or sinus barotrauma, consider transporting these in low-level flight.

Deafness or blindness is not a contraindication to flight but do present communication and safety considerations. The crew should make every effort to alleviate anxiety in these passengers. Special consideration should be given for in-flight emergencies such as rapid decompression, crash landing, or forced ditching. Elderly passengers may have hearing loss and the ambient aircraft noise will make normal communication difficult or impossible. A stethoscope may be used to converse with the patient. The flight nurse should place the ear pieces into the patient's ears and talk into the bell. This is an effective communication tool.

Aerodontalgia, or toothache, is a result of air expansion in a poorly filled cavity due to air travel. Flight crew members should delay flying for a few days after having any cavity filled to avoid pain and discomfort. Patients with poor dental hygiene may have pain while traveling. If this pain is severe, consider asking the pilot for a lower altitude.

Patients with wired jaws should have a quick release device attached in the event that vomiting occurs during flight. Cutting the fixation device with wire cutters may be an option but it is difficult and time consuming and may not prevent aspiration. A quick release device is preferred. Suction should be readily available when transporting these patients and premedication with an antiemetic should be considered.

Respiratory

Hypoxia will have a definite effect on patients with respiratory ailments. Arterial oxygenation [PaO2] will fall with increasing altitude. In a normal healthy adult, a PaO2 of 95 mm Hg at sea level will decrease to 60 mm at an altitude of 8,000 feet without supplemental oxygen [Liebman]. Patients who have a mild hypoxia on the ground will have a profound hypoxia at altitude. Pulmonary pathology that can cause hypoxia include: pneumonia, pneumonitis, pulmonary edema, pulmonary fibrosis, chronic bronchitis, acute smoke inhalation, aspiration, adult respiratory distress syndrome [ARDS], congestive heart failure, asthma, or any other restrictive or obstructive lung disease. Any patient who has primary hypoxia from any of the above disease entities must be transport with care. Additional oxygen must be given to compensate for altitude effects. These patients must be transported in a pressurized aircraft. Tracheal intubation and positive pressure ventilation may be indicated in critical situations.

Patients with Chronic Obstructive Lung Disease [COPD] can live with an arterial PaO2 in the 50 - 60 mm range. This would be the same as traveling at an altitude of 8,000 feet in a normal and healthy person. The COPD patient traveling at 8,000 feet would be oxygenating as if he/she were traveling at 16,000 feet. These patients would be at high risk without supplemental oxygen. But supplemental oxygen in COPD patients is not without risk. Since oxygen, not carbon dioxide, is the primary breathing drive, additional oxygen may suppress breathing. This may lead to hypercarbia [retention of carbon dioxide], hypoventilation or apnea. Graham and Houston and Schwartz, et. al. studied the effects of superimposed hypoxia in uncompensated emphysemics during air travel. Both studies found that in otherwise normal adults, COPD patients could tolerate short term exposure to altitude without major complications. Some subjects in the study did complain of fatigue and headache, though, which are some mild side effects of hypoxia. Yet supplemental oxygen should not be withheld from COPD patients because of the potential of hypoventilation or apnea. The Air Force has successfully transported these patients using low flow oxygen. A nasal cannula with 1 - 4 L/min flow should be adequate. Alternately, a fixed concentration Venturi type mask can deliver accurate concentration of oxygen, although changing altitude may require higher concentrations of O2. A convenient method for monitoring oxygenation during aeromedical transport is by oximeter. This device will give an accurate measure of arterial oxygen saturation by using a finger or ear probe. A baseline saturation can be obtained during the initial assessment of the patient before flight. Oxygen can then be administered to maintain the baseline ground oxygen saturation. Low level flight, with cabin altitudes below 4,000 feet may be necessary in unstable patients to avoid wide changes in oxygen availability. It must be emphasized that all patient should be continuously assessed throughout the transport. If the patient's condition changes appropriate action must be taken.

Oxygen Delivery:

Table 2: Oxygen Delivery Devices

Device	Oxygen Percent (%)	Flow Rate (L/min)
Nasal cannula	25-35	1-6
Simple mask	35-55	6-10
Partial rebreather	up to 60	6-12
Nonrebreather	up to 95	6-12
Venturi masks	24-50 [fixed %]	4-12
Manual bag	40-100	4-15

A nasal cannula will be better tolerated in the awake and conscious patient. Liter flows above 6 L/min may cause discomfort, though. A mask may give feelings of suffocation but can provide higher oxygen concentrations than the nasal cannula. Venturi masks will hold a fixed concentration of oxygen with a set liter flow of oxygen. Venturi masks are reliable over a wide range of altitudes yet typical masks require high liter flows of oxygen. This makes them impractical in the transport environment due to the limited supply of O2 on board the aircraft. Airway adjuncts may be used when necessary to maintain airway patency and to aid ventilation. These devices include: oral and nasopharyngeal airways, oral screws, suction apparatus, and manual bag resuscitators. Always have a bag-mask apparatus available to assist respirations. Know your equipment and keep it readily available.

Mechanical ventilators can be carried in flight and are quite effective. There are two categories of ventilators are appropriate for air transport: small gas powered models and compact volume ventilator used for home care. The gas powered machines are acceptable for short transfers but consume an excessive amount of oxygen [16 L/min or more]. Volume ventilators such as the Life Products LP6 are powered by electricity [battery and/or onboard 110v power] and use lower flows of oxygen 2-6 L/min to maintain the required oxygen concentration. These home ventilators can be awkward to use because of their size [approximately 9 in. x 12 in. x 12 in.] and weight [32 lbs.]. When planning a ventilator trip have the following equipment available: appropriate ventilator; at least two sources of power [internal and external battery, 110volt inverter, 12volt aircraft source]; two sources of suction and the proper suction catheter size; a manual resuscitator bag; intubation equipment and replacement airway [such as tracheostomy tube]; enough oxygen to cover the entire trip as well as contingencies such as diversion, increased oxygen needs, equipment failure, manual bagging, etc.; an oximeter with backup probe; and an oxygen analyzer. Ventilator transports are safe if the proper equipment and personnel are available.

An additional consideration with artificial airways is the problem of pressure changes on the cuff of the endo/nasotracheal tube or tracheostomy. During climb, the air in the cuff will expand and put undue pressure on the trachea. On descent, the cuff volume will fall leading to an air leak and decrease in ventilation. One author advocates filling the cuff with sterile water [Stoner, 1976]. Water volume is not affected by pressure changes but may make the cuff rigid and therefore cause tracheal damage. Another strategy is to adjust the airway cuff as needed during climb and descent. This will require constant vigilance by the flight crew and it will be difficult to listen for an air leak in the noisy cabin. A new product called the PressureEasy Cuff Pressure Controller®can be used to compensate for varying cuff pressures. This device is easy to use and is effective..

Airway drying of the lips, mucosa, and trachea is possible during long flights because of the dryness of cabin air. Ambient humidity can be as low as 10% in jet aircraft. Salve or lemon glycerin swabs may be used for the lips. Do not use petroleum products such as Vaseline when patients are receiving oxygen therapy because the reaction with oxygen may cause burning of the skin. Patients with artificial airways are also at high risk for airway dehydration, thickening of pulmonary secretions, and possible plugging of the airway. The combination of dry respiratory gasses and low humidity increases insensible losses through the respiratory tract. An artificial filter called a Humidivent®can be used with an artificial airway. Place the device inline on the external flange of the tube. It can retain as much as 50 - 60% of the airway's moisture. This device also retains much of the natural temperature of the trachea. The Humidivent should be used on all patients with tracheostomy, endotracheal, and nasotracheal tubes. Never premoisten the device since water will cause the filter to swell and decrease air flow. Also, mucus or other secretions can accumulate in the Humidivent and occlude flow. When using this device, monitor ventilation continuously and check to make sure that the filter does not become clogged.

An associated problem with respiratory care at altitude is decreased air density. This may interfere with the cough mechanism by reducing expiratory pressure and produce a less expulsive cough. A patient may not be able to clear his/her secretions. On the other hand, decreased air density can reduce the work of breathing, especially in patients with increased airway resistance. Patients who have increased sputum production may have problems during flight. Coughing and breathing exercises, also positioning for postural drainage and tracheal suctioning may be important elements of care for these patients in-flight.

The dangers of transporting a patient with a pneumothorax without chest drainage are real. Trapped intrapleural air will expand by 25 - 30% at 8,000 feet, and 50% at 18,000 ft. This can potentially cause a tension pneumothorax if untreated. Any existing pneumothorax should be decompressed with a chest tube before air transport and an x-ray should be obtained shortly before flight to determine the effectiveness of chest decompression.

One study found no incident of spontaneous pneumothorax for civilian travel via pressurized commercial aircraft. We can conclude that air travel at cabin altitudes less than 10,000 feet represent little risk for patient or crew if there is no existing chest pathology. Yet patients with a history of pneumothorax, TB, or blebs [emphysema patients], should be evaluated carefully and transported at a low altitude, preferably below 8,000 feet.

Patients who have indwelling chest tubes present a problem during aeromedical evacuation. Underwater seals using Pleurovacs or other chest drainage setups are unreliable during patient movement and aircraft turbulence. Glass bottle drainage, for obvious reasons, should never be used for transporting patients. A Heimlich valve should be used on all chest tubes. This device acts as a one way flutter valve allowing air and fluid to drain from the pleural cavity but prevents reflux of air or fluid back into the chest. You can use a simple sterile collection device - such as a urinary bag. This avoids bringing a bulky chest collection device. As a practical matter, medical flight crews should have Vaseline gauze, Hemilich Valves, and several chest tube clamps in their flight kits.

Cardiovascular

There is considerable debate over the transfer of patients with acute or recent myocardial infarction. Conventional judgment as outlined by the American Medical Association*** (1983) delays air travel four to six months post infarct. Yet modern invasive cardiology has created life saving therapeutics that can significantly decrease mortality and morbidity. Kaplan, Walsh, and Burney recently studied patients transported by helicopter who were experiencing acute myocardial infarction. They found aeromedical evacuation not only safe but potentially life saving. Fixed-wing transport presents the same possibilities for safe transfer of patients with acute or chronic cardiovascular disease.

Hypoxia will affect the cardiac patient. Those with coronary artery disease may experience angina. Supplemental oxygen can readily compensate for the decrease in ambient oxygen. But fear and anxiety may pose a different problem. Release of circulating catecholemine from anxiety and fear may cause cardiac irritability and dysrhythmia.

Turbulence is also a problem and may hasten motion sickness and the possibility of Vagal stimulation and bradycardia. EKG monitoring of these patients is essential and aggressive treatment of dysrhythmia may be indicated.

The ability to perform advanced life support and basic CPR inside the aircraft cabin presents some problems. Access to the patient may be difficult when performing interventions such as intubation and starting IV's. Turbulence and noise will create additional problems. All patients requiring advanced life support must have two appropriate medical crew members. If a cardiac arrest occurs during flight, a reasonable alternate airport landing should be selected. It may be advantageous to fly a few extra miles to reach a major metropolitan area where sophisticated care is certain. Plan for contingencies during preflight and know what alternate airports are available along the route of flight. If a problem occurs during startup or taxi, return to the airport and stabilize the situation. It may be better to return to the referring hospital than to carry out CPR a few minutes after takeoff.

Prolonged inactivity in the cramped quarters of an airplane can result in venous stasis, poor venous return, and low cardiac output states. This, in combination with gravitational pooling from acceleration forces, can produce extremity edema, deep vein thrombosis, and possibly an embolus. Patients at risk for deep vein thrombosis should be instructed to exercise frequently and move about as much as possible. A thorough evaluation of the lower extremities including pulse character and calf pain [Homan`s sign] should be included in the preflight assessment of all patients. Patients with sickle-cell trait or sickle-cell anemia are at risk for developing crisis. Green reported several cases where sickle-cell patients have experienced infarctive crisis while traveling on pressurized aircraft at a cabin altitude of 5,000 feet. Any patient with sickle-cell trait or disease should receive supplemental oxygen for the duration of the flight.

GI/GU

Abdominal distention can result from cabin altitude changes. The gut contains approximately 0.5 to 1.5 liters of gas. At an altitude of 8,000 feet this will expand by approximately 25%. In patients with recent surgery or abdominal pathology, the expansion of abdominal viscera could possible rupture internal sutures and cause hemorrhage or peritonitis. Bowel anastomosis are at risk and wound dehiscence can occur due to abdominal distention as late as ten days post surgery. Unsupported hernias may become strangulated and cause circulatory compromise. Gas expansion in the abdomen can cause respiratory embarrassment by diminishing diaphragm movement. These problems were noted in the 1930s when German transport planes transported troops over the Alps at an altitude of 16,000. Shock from internal hemorrhage and respiratory compromise from crowding of the diaphragm were noted with some abdominal injuries. In pregnant or obese patients, splitting of the diaphragm due to distention has been reported*** (Johnson, 1984). Abdominal gas expansion can be a real problem in patients with small bowel obstruction, ileus, abscess, or recent surgery.

A nasogastric tube is essential treatment in these patients. The NG tube, ideally, should be placed to continuous suction throughout the transport for decompression. There may be some limits on battery operated suction equipment, though. On long flight, place the tube to continuous suction during initial climb and then intermittently for the remainder of the flight. As an alternative, use a catheter tipped syringe to provide intermittent manual suction during the flight. Continually assess the abdomen for distention and pain. Take vital signs often and be suspicious if heart rate increases or blood pressure decreases. These may be signs of hemorrhage or impending shock.

Patients with ileostomies or colostomies will experience increased bowel evacuation and extra large drainage bags should be applied before flight. Gastrostomy or other feeding tubes should be evacuated before flight. During initial climb place a catheter tipped syringe on the gastrostomy tube to remove excess air. Patients with continuous tube feedings should be specially handled. If a trip is short, hold tube feedings one hour before flight and aspirate residual. For long trips, i.e., greater than four hours, consider giving bolus feedings enroute to assure adequate hydration and prevent hypoglycemia. Gastric regurgitation and possible aspiration during flight and patient handling is a real concern during a particular mission. Evaluate each patient individually and hold tube feedings if vomiting is possible. Obtain a baseline finger stick glucose before transport and obtain one or more during flight to screen for hypoglycemia. Give high concentration IV glucose if this is a problem.

Bladder distention should not be a problem since the bladder usually holds no air. Any condition that will introduce air into the bladder, though, will have the same problems with gas expansion. Indwelling urinary catheter balloons are filled with sterile water and will not expand. Use care to maintain the patency of urinary drainage devices. Back flow of urine must be avoided to prevent contamination of the bladder. These catheters should be taped or secured because of the danger of pulling out a catheter during onloading or offloading of the patient. Collection bags should be placed on the floor of the aircraft and tubing should be dressed to allow the free flow of urine. Free air in the collection bag will expand, therefore vent the bags during initial climb to prevent the bag from rupturing and creating a messy situation.

Orthopedics

Patients who experience bone fractures will usually have some swelling and hemorrhage to soft tissue. This will lead to pain and circulatory disturbances. Any further manipulation of the fracture, such as loading into the aircraft, may cause further rebleeding and tissue swelling. This can occur as late as fourteen days post injury. Special considerations must be given to these patients. Air trapped under a cast will expand and possibly cause circulatory compromise. Therefore all fresh casts should be bivalved or split. Windows should be placed over any wound or vascular injury. Conduct a thorough assessment of distal perfusion before loading the patient. Frequently assess distal circulation, especially during ascent, and observe for color and warmth of the extremity as well as quality of the distal pulse. Pain may be an early sign of constriction. Avoid manipulating the fracture or cast.

Spika casts may present some unusual problems in aeromedical transport. First, the problem of abdominal distention against the cast may cause constriction of ventilation or precipitate vomiting. Loading these patients can be a problem. It may be difficult or impossible to get a patient in a spika cast through the cabin door. Consider the possibility of a forced off-field landing. Could you get such a patient off the aircraft? Careful planning during the preflight phase is needed to determine whether these patients can be transported safely.

Patients in traction present some interesting problems for aeromedical evacuation. Balanced traction with weights is absolutely contraindicated. It is impossible to maintain proper alignment and traction. Free swinging weights also pose a serious safety hazard. Traction can be maintained by using commercial devices such as the Hare or Sager traction splints. Patients with external fixation devices can be transported by air. Attention should be given to comfort and extra pillows brought along to pad and elevate the extremity. Use extra care during loading to avoid bumping these devices.

Air splints have little value in an aeromedical environment due to dynamic pressure changes. On ascent, the air splint will expand and compromise circulation. On descent the air splint will loose its rigidity and ability to splint the injury. Air splints are not routinely used during air transport.

Military Anti Shock Trousers [MAST] will also be affected by changes in altitude. Sanders & Meislin ***(1983) showed a direct correlation with increases in altitude and increases in MAST suit pressure. With an increase of altitude to 7,000 ft. the MAST suit pressured tripled. Correspondingly, when descending from high altitude, MAST suit pressure dropped to near zero. If the MAST is used during flight, carefully monitor its pressure. Other problems related to MAST use such as potential for compartment syndrome, restricting respiratory expansion, and increasing intercranial pressure will be exacerbated by unmonitored changes in the pressure garment. The abdominal compartment should not be inflated because of the danger of compromising respiratory excursion. [If the MAST is to be used to stabilize a pelvic fracture, the risks of respiratory embarrassment through inflation of the abdominal compartment must be carefully weighed by the attending aeromedical physician.]

Burns

Specialized burn care is effective in reducing mortality and morbidity (Treat, et al., 1980). Because of the low incidence of critical burns in a particular geographical area and the unusually long distance to burn centers, aeromedical airlift may be needed. Transport by air can exacerbate a few problems. First, decreasing cabin altitude produces hypoxia. Existing hypoxia due to smoke or inhalation injuries is compounded. Second, the burn injury will predispose the patient toward temperature instability and increased insensible losses in the dry cabin environment. Thermal stress is also a problem when the patient is exposed to the outside environment. Temperature instability is a problem in all burn patients. Finally, the potential for infection is increased, therefore the patient must be protected with sterile dressings.

Strict attention must be paid to respiratory care, airway patency, IV access, and hydration. Baseline labs, especially arterial blood gasses and carboxyhemoglobin measurement should be obtained before transport. Carbon monoxide will produce hypoxia and administration of 100% oxygen is appropriate to wash out carbon monoxide. Tracheal and airway edema resulting from the burn injury may be rapid or insidious. Any doubts about the patency of the patient's airway should be addressed prior to transport. It may be difficult to secure an adequate airway during transport. Adequate humidification of the airway is also a difficult problem in burned patients. Use a humidivent on all artificial airways and use sterile saline to keep the tracheal mucosa moist. Assess airway patency frequently and be aware of compromise from burn debris or mucus plugs.

At least two intravenous lines should be placed before transport. This ensures IV access if a line should be accidentally dislodged during transit. Large bore lines such as a 16 or 14 gauge angiocath should be used so that high flows of fluid can be maintained if needed. Hydration in the burn patient can be measured by hourly urine output. Fluids should be increased if oliguria [less that 30cc urine per hour] occurs. Fluid requirements will be higher in aeromedical evacuation because of increased insensible losses from a dry aeromedical environment, especially in high altitude jets.

Temperature stability in the burn patient is a problem, especially during the winter months. Exposure to cold should be minimized. The patient can be wrapped in a Mylar or Space blanket to reduce radiant and convective heat losses. Sterile dressings should cover all burn surfaces and the integrity of the dressing should remain intact. Do not cover extensive burns with saline soaked sterile dressings because of potential for shivering and hypothermia.

Frequent checks of peripheral pulses must be done to evaluate potential for circulatory compromise due to circumferential burns. An escharotomy may be necessary if swelling compromises circulation to a particular limb or respiratory embarrassment occurs with chest/abdominal burns. Continually evaluate the patient for cyanosis, impaired capillary filling, progressive loss of sensation in an extremity, or increasing dyspnea with chest/abdominal full thickness burns. If any of these occur, consider an escharatomy. Ideally, an escharatomy should be performed before transport and covered with sterile dressings.

All patients with significant burn injuries (greater than 20% of body surface area) should have nasogastric tubes inserted due to the high percentage of ileus. Trapped intestinal gas will expand at altitude and potentially cause respiratory embarrassment and discomfort. Place the gastric tube to low suction during the flight or use a catheter tipped syringe to provide manual intermittent suction during the mission.

Address pain control during the flight. Burn patients will frequently experience excruciating pain from their injuries. Use enough intravenous pain medications to provide symptomatic relief but avoid respiratory depression and hypotension. Always have Narcan available to reverse the side effects of narcotic analgesics. Never give pain medications by intramuscular route due to poor absorption from the burn injury and possible delayed response.

Infectious Disease

Patients with communicable diseases pose a risk to the crew. Yet communicable disease is not necessarily a contraindication to flight. Several concepts are involved regarding treatment and transportation of patients with infectious processes. First, the crew and passengers must be isolated from the source of infection. Exposure can come from many sources but mainly through direct contact with contaminated body fluids or through infected droplets of air exhaled by the patient. Second, contamination of the aircraft and other personnel by soiled linens, needles, dressings, etc., must be avoided. Lastly, patients may be at risk of contamination from the flight crew or passengers [or other ground personnel. Several isolation techniques are addressed:

Wound and skin isolation: Contaminated wounds or external body parts must be covered with sterile dressings. The dressings should remain intact throughout the flight unless there is a substantial reason for removing them. Any saturated dressings should be reinforced not replaced (if possible). Contamination of the aircraft and crew is possible with direct contact. Therefore any person having contact with the patient should wear gloves and a gown. Likely pathogens include: Clostridium [gangrene], local Staph infections, conjunctivitis, cutaneous diphtheria, impetigo, pediculosis, Rabies, Scabies, and skin lesions resulting from Herpes type virus.

Enteric isolation: Infected blood, serum, or feces will pose a hazard. Likely pathogens include: Hepatitis, Salmonella, Shigella, Amebic Dysentery, Cholera, Giardia, Necrotizing Enterocolitis, Typhoid, Malaria, Polio, and other infectious blood or stool borne bacteria or virus. Patients with infectious diarrhea may be a problem during flight. Besides the obvious problem of attending to bowel elimination in the aircraft, copious amounts of infected diarrhea may present a problem with handling and isolation. It may be wise to wait until diarrhea has subsided before transporting these patients.

Respiratory isolation: Simple respiratory infections can be isolated by a face mask. Since the main transmission is by infected droplets, gloves and gowns are not necessary. Likely pathogens include: tuberculosis, Measles, Mumps, H-influenza, epiglottis, and Ptussis. Care should be used in disposing sputum since it is also contaminated.

Strict isolation: Certain infections require maximum isolation between crew and patient. These include: diphtheria, Lassa or other hemorrhagic fevers, Pneumonic plague, Small Pox, Chicken Pox, resistant Staph septicemia, and Disseminated Zoster. Gowns, gloves, and masks are required at all times by all passengers and crew members.

Protective isolation: When a patient is not infected but is at high risk for cross contamination then the crew must wear gloves, gowns, and mask to prevent exposure to the patient. Two types of patients are in danger: immunosuppressed patients and burn patients.

Handwashing is a crucial element in eliminating potential for cross contamination. Yet most aircraft do not have running water and soap. An alternative is to use antimicrobial foam agents. These are quite easy to use. Foam is dispensed from a small can resembling shaving cream. The foam is rubbed into the hands for one to two minutes until dry. If hands are grossly contaminated with blood or other body secretions other agents may be helpful. For example using alcohol or hydrogen peroxide to remove gross contamination can be used with the antimicrobial foam.

Handling of soiled linens, needles, and patient care items is another consideration. All infected linens should be double bagged and if possible, sent with the patient. Needles should be disposed of in a special receptacle [a contaminated needle box for example], or a clean urinal or empty plastic bottle may be used. Do not dispose of the contaminated needles using normal garbage. Contact the local health care agency on how to dispose of contaminated material. Decontamination of the aircraft after flight should be thorough. An effective and inexpensive bacterial and viralcidal agents is sodium hypochlorite [or common bleach]. Dilute the bleach with tap water and mop down all interior surfaces. Other cleaning agents may be needed to remove dirt and grime. Use a disinfectant spray such as Lysol to remove offensive odors.

Another transport consideration is fever. Fever in any patient suggests an infectious process unless otherwise indicated [such as head injury]. The specific source of the fever must be known before air evacuation. Some causes of fever can be lethal in the aeromedical environment such as an untreated abscess that could rupture into the peritoneal or pleural cavity due to pressure changes High fever may lower the seizure threshold and predispose a patient to active seizures. Fever also increases caloric needs and increases insensible losses. Normally, no patient should be transferred with a body temperature of more than 102 degrees.

Pediatrics

Children, infants, and neonates present distinct problems in aeromedical evacuation. Young children and infants are prone to temperature stresses and dehydration. Newborns, especially premature infants, are unusually susceptible to the stresses of flight. Yet the benefits of having a transport team with the proper equipment and training is potentially lifesaving. Roy & Kitchen reported a two thirds decrease in mortality of premature babies who were flown in aeromedical aircraft using highly trained neonatal transport crews. This gives credibility to the use of fixed-wing aircraft for pediatric transport, especially when time is critical.

The risk of hypothermia cannot be overstated. Most infants are usually temperature unstable for several days after birth. Hypothermia in the newborn can yield acidosis, hypoglycemia, and hypoxemia. Pulmonary shunting will increase and death may follow unless corrective action is taken. Heated isolettes must always be used in transporting infants and temperature must be carefully monitored. In very cold environments, a space blanket can be placed around the exterior of the isolette to decrease heat loss. The heat loss from the isolette can be as high as 12 degrees C per hour in near freezing temperatures. Chemical heating pads can be used to produce supplemental warmth but can be dangerous if the chemical leaks from the bag. There is also a danger of overheating the infant. Infants cannot communicate their needs therefore the aeromedical crew must be especially watchful.

The problem of noise in the aeromedical has been described. All infants should have ear protection, not only inside the aircraft, but throughout transfer from hospital to hospital. Humidification of artificial airways has a special importance in pediatric transport. The small tracheal tubes are more likely to be blocked by dried pulmonary secretions. The Humidivent can be used just as effectively in pediatric or adult transfer. Frequent suctioning and position changes should be carried out. All tubes must be checked and secured before moving the child into the aircraft. Intubation of a child in the airplane will be extremely difficult.

Pediatric patients who present with epiglotitis or severe croup with stridor present a real problem for aeromedical transport. Travel to the airport with all of its strange noises and activity will be frightening to the child. Further anxiety and distress can close the airway. It may be reasonable to defer transfer until the airway is stable.

Gastric decompression is mandatory in critically ill pediatric patients. Abdominal distention can be life threatening because of respiratory compromise. Abdominal distention can press against major arteries and veins leading to decreased perfusion and cardiac output. The gastric tube should be connected to suction to evacuation air and stomach contents. Check placement of the tube before onloading the patient and assure patency throughout the trip with boluses of saline. Do not use air because it can cause further abdominal distention. Dehydration of infants and children due to insensible losses is more of a problem than adults because children have a greater body water content. Infants and young children should be given frequent supplements of water or electrolyte solution throughout the trip if they can take fluids by mouth. The sucking and swallowing mechanism can be helpful in equalizing air pressure in the middle ear on descent thereby minimizing ear trauma.

Flying may be unfamiliar to children and can be quite frightening even to adolescents. Always reassure the child and calmly explain the different noises and sensations. Parents, except in extreme emergencies, should accompany the patient. If the child wishes and is able, he/she may sit on a parent's lap. The seatbelt should not be wrapped around both the child and adult, though. Use a second belt around the child and attach it to the parent's belt. Infants should be carried in a car seat and should be placed on the stretcher against the forward cockpit divider and face rearward. One or two stretcher straps will be needed to secure the car seat. Secure an isolette, if used, securely to stretcher. Some teams have adapters that use the aircraft's seat tracts. Be familiar with their operation.

Mental Health

Patients with known psychiatric diseases will be sensitive to the strange environment of flying. Unfamiliar people, strange noises and smells, and unusual sensations such as takeoff and landing can lead to disorientation, agitation, or acute psychotic behavior. Elderly patients are also at risk as they may be away from their familiar surroundings for the first time in many years. Isolation, fear, claustrophobia can add to an unpleasant experience. This is true for all patient not only the elderly or those with psychiatric disease. Sedation may be indicated in some circumstances but anticholinergic agents such as the phenothiazines and tricyclic antidepressants tend to increase intestinal gas and lead to gastric distention. Sedation also diminishes a patient's ability to communicate distress. Use restrains sparingly but do not jeopardize the crew with an unruly or combative patient. It is difficult to advocate air transfer of combative patients because of the danger of distraction of the pilot or even the remote possibility that the patient may come loose and endanger the crew. These patients must be carefully evaluated. If there is any question regarding the safety of flight, these patients should not be transported by air. If a patient must be restrained, evaluate circulation frequently and observe for skin breakdown and nerve palsy due to aircraft vibration.

Lastly, the fear of flying can provoke anxiety that could lead to fatigue and predispose the patient [also passengers] to motion sickness. Assume that patients and passengers are unfamiliar with flying and be reassuring to them. Some passengers may be hesitant about flying in a "small airplane". The attitude that the crew portrays will be significant. If you are hurried and abrupt in your approach, you may further increase the anxiety of your patient. Always be aware of your patient's psychological needs as well as their physical needs.

Mission Management

A number of different factors must be addressed in order to achieve a safe aeromedical transfer. Consideration must be given to both preflight assessment and preparation as well as enroute patient care. Is the mission warranted? What are the aeromedical consequences of travel by air? Are there alternatives to travel such as ground vehicles or scheduled airlines?

The mission coordinator should have a thorough understanding of the patient's needs before committing to a flight. Assessment of a patient by telephone may be difficult. The referring physician may overstate or underestimate the overall medical status of the patient. Problems which may seem insignificant to the referring physician such as a minor pneumothorax may not be reported. The condition of the patient may be understated in order to expedite a nonpaying patient out of a hospital. Foreign requests present language and cultural barriers. Phone service may be nonexistent or at best difficult. Procuring necessary documentation and insurance for out of country flights may also present some problems.

Preflight Phase

Preparation for a flight begins with the initial contact from the requesting agency or person. Preliminary data and information will be obtained. A general go/no go decision can be made based on the appropriateness and feasibility of the request. Once a mission is accepted, coordination of the individual flight will begin.

Flight coordination

Once a patient is accepted for air ambulance transfer the appropriate aircraft must be selected, crews assembled, and ground transportation arranged. Organizations who have the luxury of choosing between piston-prop, turboprop, and jet aircraft will need to look at the distance needed to travel. As a rule of thumb, distances up to 500 miles can be handled easily by piston-prop airplanes. Turboprop aircraft become increasingly effective between 500 and

1,500 miles and jet aircraft will usually be indicated for distances beyond 1,500 miles. Yet it is conceivable to take a piston prop airplane on a long trip or use a jet for a distance of a few hundred miles. The main considerations in choosing an aircraft are trip length, runway length needed, anticipated weather, and cost. Speed can be a critical factor. Patient who must be moved quickly will benefit from the speed of jet aircraft. Yet for most routine air ambulance transfers, speed is more a matter of convenience rather that necessity. The flight schedule will need to be calculated. This is generally delegated to the mission coordinator but it is helpful for the crew to know how this is done:

1. determine the airport itinerary. All airports have a single unique three letter/number identifier. For example Charlotte, NC is CLT.
2. determine the distance between each airport. This can be stated as statute or nautical miles [note: most aeronautical charts will show distance as nautical miles].
3. determine the time enroute between each airport. This is not as simple as it sounds. Average speeds can be used for each particular airplane, for example a Piper Cheyenne turboprop averages 230 MPH. Yet this is a variable number. On shorter trips such as 150 miles this plane may average only 200 MPH. On longer trips, especially in jets, the average speed can be greater. Head or tail winds will also change time enroute. Weather and air traffic will also add additional time.

Probably the best strategy is to use a set average speed and adjust for wind or stage length as needed. This is one of the reasons why it is important for the flight team to have air to ground communications. Estimated arrival times can vary as much as an hour or more and ambulances will rarely wait at an airport if a flight is long overdue. It is possible to be placed in the embarrassing position of trying to arrange for ground ambulance transfer at the airport with the patient waiting onboard.

- select an operator on the airport where the ground ambulance can meet the plane. Several books are available which list field operators [known as fixed base operators or FBO's]. It is important that this is arranged with the ambulance company since a particular airport may have a number of FBO's.
- coordinate with the pilot on refuel stops for long trips. Know the airplane's range and performance limits. Following is a sample itinerary of a Cheyenne turboprop from Charlotte, NC [CLT] to Richmond, VA [RIC] to Teterboro, NJ [TEB], and home to Charlotte:

Table 3: Aircraft Comparison

	AIRCRAFT		MPH	TAIL #	$/MI.	BASE
	7	BE-90B	225	N301DK		CLT
FROM	TO	DIST	FLT TIME	DPT	ARR	GND
CLT	RIC	255.9	1:08	7:00	8:08	1:30
RIC	TEB	289.2	1:17	9:38	10:55	1:30
TEB	CLT	539.1	2:23	12:25	14:49	0:00
CLT	CLT	0.0	0:00	14:49	14:49	0:00
		0.0	0:00	14:49	14:49	0:00
		1,084.2	4.8		7:49	Mission Time

Note: all distances are in statute miles, aircraft average speed is in statute miles per hours [rather than Knots]. Read across as:

Depart Charlotte [CLT] at 0700 and arrive in Richmond [RIC] at 0808, 1 hour and 8 minutes estimated time enroute, 1 hour 30 minutes to travel to referring hospital, assess patient and transfer by ground ambulance to RIC. Arrive in New Jersey - Teterboro [TEB] at 1055 after 1 hour 17 minute flying time and an hour and a half to take the patient to the receiving hospital. Be sure to leave time for crew rest and lunch. In this example, time was planned in Teterboro so the flight crew could go to an excellent German deli just outside the airport. The hot Pastrami sandwiches are highly recommended.

Contraindications for aeromedical evacuation

There are no absolute contraindications to air transfer when a life is at stake but a number of medical conditions present a relative contraindication when the risks of air transport do not outweigh its benefits. This list is compiled from a number of sources (Parsons & Bobechko, 1982; Voss, 1983; Moyland, 1974; American Medical Association, 1982):

- Diving accidents [dysbarism]: Pressure changes can have profound effect on dysbarism and exacerbate the production of nitrogen gas. Divers, under normal circumstances, should avoid any air travel up to twelve hours post dive.
- Untreated pneumothorax: Gas expansion can change a simple pneumothorax into a tension pneumothorax;
- Unstable airway: A patent and effective airway should have the crew's utmost attention. Serious complications and death can occur with hypoxia of as little as three minutes;
- Recent chest surgery: Extraneous air may lie in the chest cavity for as long as three weeks. If this patient must be transferred, a chest x-ray should be taken shortly before transport to assure that an untreated pneumothorax is not present. Chest tubes should not be discontinue within 72 hours of a flight;
- Pneumonia: Profound hypoxia may develop despite supplemental oxygen. If the patient is unable to maintain a PaO2 greater than 60 mm Hg on 40% supplemental

oxygen at sea level, consider the possibility of intubation and positive pressure ventilation for the transfer;

- Recent abdominal surgery [less than 14 days post procedure]: Trapped intra-abdominal air will expand at altitude and may compromise internal sutures, anastomoses, and general circulation. Small bowel obstruction presents a similar problem with gas expansion and possible circulatory compromise to vital abdominal organs;

- Air in the cranium or recent craniotomy: This follows the same principle of gas expansion in any body cavity. Since the cranium is a rigid vault, expanding air inside the skull presents a much more dangerous problem inflight. As little as 20cc of air [or blood] can cause herniation;

- Gas gangrene: Gas bubbles produced by the Clostridium bacteria will expand with altitude further compromising circulation.

- Combative or unruly patients may pose a flight hazard;

- Balanced traction: is not possible in the aircraft and poses a safety threat due to the free swinging weights. Alternatives to balanced traction are necessary when transporting patients with fractures requiring traction.

- Retinal detachment or severe retinopathy: hypoxia may cause further damage to the retina;

- Sickle cell anemia: hypoxia may precipitate a crisis;

- Radiation contamination: will expose crew and aircraft to contamination;

- Recent myocardial infarction or cardiac failure: This is quite relative. Although some authors recommend air travel for these patients because it is less tiring than by typical ground transport, one must consider the consequences of hypoxia, anxiety, motion sickness [possible vagal stimulation], and dysrhythmia during transport. On the other hand, Voss claims that if a post infarction patient is allowed unlimited ambulation by his physician then he is medically cleared for flight. Supplemental oxygen for cabin altitudes above 4,000 feet are recommended. Cardiac monitoring may be indicated for patients at risk for dysrhythmia;

- Severe anemia - Hb less than 7.5 mg/dl chronic or 10.0 mg/dl acutely: Since the red blood cell is the major transport mechanism of oxygen, severe anemia will intensify the effects of hypoxia. Every attempt should be made to correct anemia prior to flight. Active bleeding may be difficult to control during aeromedical transport and blood will not be available. Rebleeding from the GI tract due to internal gas expansion or bleeding from fracture sites is always a possibility;

- Uncontrolled hyper/hypothermia: The aeromedical environment can produce dynamic and extreme temperature shifts. Control of core temperature can be difficult under normal circumstances. Hyperpyrexia [high temperature] or hypothermia [low temperature] before transport may be worsened. Control of body temperature in the aircraft can be difficult;

- Unstable vital signs such as profound shock, severe brady/tachy dysrhythmia, or other unstable cardiac dysrhythmia: The stresses of flight amplify such problems and they may be difficult to correct inflight. Attempt to stabilize the patient prior to transport. The cabin of a moving airplane is not an ideal place to treat such emergencies.

The relative risks of aeromedical transport should be weighed against its benefits. Common sense and prudent judgment should prevail. The relative emotional urgency in attempting to bring a patient home during an acute illness in a distant city may not be worth the risk. For example, a patient who has suffered an acute myocardial infarction should not be moved unless medically indicated. If this patient is receiving appropriate medical treatment, then transport home should be delayed until the patient's condition is more stable. On the other hand, the risk of aeromedical transport may outweigh the benefits of local treatment when the capability of the facility can not meet the patient's needs. For example, a tourist who is involved in an auto accident while vacationing on a small Caribbean Island may need the sophistication of a major medical facility to attend to his injuries. Rapid aeromedical evacuation may be indicated in face of a deteriorating condition.

Altitude restrictions

Relative contraindications to aeromedical transfer have been addressed previously. When a flight is deemed medically necessary, careful planning for patient care should be carried out. The following are recommendations for altitude restrictions for various medical problems which may be encountered:

Sea level or minimum cabin altitude [or below 4,000 feet]:

- Diving accidents;
- Distended abdomen, i.e., small bowel obstruction;
- All patients within 48 hours of eye, chest, cranial, or abdominal surgery;
- Gas gangrene;

4,000 feet:

- All unconscious patients;
- All critically ill or unstable patients;
- Acute myocardial infarction and/or congestive heart failure;
- All patients with fresh casts [less than 48hrs];
- All patients with history of ear or sinus block;
- All patients with chest tubes;
- All patients receiving 40% supplemental oxygen at sea level with PaO2 less than 65 mm Hg [positive pressure ventilation may be needed at a higher altitude];

6,000 feet:

- Any patient on oxygen.

8,000 feet:

- All other patients, passengers or flight crew.

Enroute Phase

The enroute phase of the transport covers the time when a patient is received by the flight crew until he/she is discharged to a ground ambulance or hospital. The medical flight crew is directly responsible, accountable, and liable for the patient during this period.

Preparation for aeromedical transport

Preparation for transport occurs during the initial screening and workup. Patients should receive maximum medical therapy prior to air evacuation. Oxygenation and ventilation should be optimal, anemia and electrolyte imbalances should be corrected, hydration should be adequate, hemorrhage controlled, and intravenous access assured [if indicated].

For elective transfers, the medical crew should call the nursing station the night before a trip for a report. History and labs should be reviewed and any preflight orders confirmed [such as additional labs, chest x-rays, preflight sedation or antiemetics, and so forth]. Arrival/departure times and airport locations should be confirmed. Also verify that copies of the chart and x-rays have been compiled. A call to the unit the morning of the flight may be indicated to follow up on preflight orders or patient condition.

The flight crew may travel to the referring hospital to pick up the patient or meet the ambulance at the airport. From a practical standpoint, traveling to the hospital adds a minimum of one hour to each leg of the trip. If the patient is stable and does not need advanced life support monitoring or equipment, it may be better to stay with the aircraft. On accepting the patient, attend to transport concerns. The following may be indicated:

- Stabilize the airway. This is the most important duty of all flight crews. A thorough assessment should be made of oxygenation and ventilation. Suction and oxygen equipment must be operable and readily available. Oxygen should be administered when appropriate. Artificial airways should be secured and checked for patency.

- Patients with chest tubes should have a Heimlich Valve®installed inline. Chest tube dressings should have occlusive Vaseline to prevent air entry into the chest. Pleurovacs [or equivalent chest drainage devices] and bottles should not be carried if possible. A sterile urinary drainage bag hooked into the Heimlich valve makes an excellent collection device. All connections should be checked for tightness and secured with tape. Use extraordinary care during onloading and offloading these patients to avoid pulling out a chest tube.

- If a patient is to be monitored, delay using the flight team's monitor to conserve batteries. Take the time to get good lead placement. This will help to avoid artifacts later in the flight.

- IV's should be checked for patency. A second large bore IV should be started for all critical patients. All tubing connections must be checked for security. Pay particular attention to central venous lines because of the danger of air embolism. Any bottle should be replaced with a plastic container if possible. If unable to get a plastic IV, wrap the bottle in a plastic bag and tape it. Place a syringe on the vent port to provide access for expanding air.
- Place all vasoactive drugs on infusion pumps. Have a piggyback line ready if the drug needs to be discontinued.
- Nasogastric tubes should be inserted for all seriously ill or critical patients. This will help relieve gastric distension which may contribute to respiratory compromise. Place NG tubes to continuous low suction during takeoff and initial climb. After climbing to altitude, conserve suction batteries and use a catheter tipped syringe or use the suction intermittently.
- Secure urinary drainage tubes with tape and check connections. Vent the drainage bag if a port does not exist.
- Patients with casts or traction devices should have padding placed over bony prominences because of the danger of skin breakdown from vibration. Fresh casts should be split or bivalved prior to pickup. A cast cutter should be part of the flight medical kit in the event that an old cast is compromising circulation and needs to be opened.

Flightline assessment

All patients must be assessed prior to onloading. This assessment will provide a baseline data for continuing care throughout the trip. A number of methods can be used but generally a head to toe physical exam and a systems review will be appropriate. The medical crew chief will determine whether a patient is suitable for transfer. The flight crew has the right and obligation to refuse a patient for transfer if, in the opinion of the crew, aeromedical transfer may be harmful or hazardous. For example, an ambulance may bring a patient to the airport with an untreated pneumothorax. At altitude this pneumothorax can produce serious problems and even death yet on the ground it may be insignificant. The initial assessment also provides a baseline for unanticipated changes. For example, a patient with a cast may have strong distal pulses when first assessed but at a cabin altitude of 6,000 feet these can become weak or absent due to the expansion of trapped air underneath the cast. If the crew did not check pulses prior to flight it would be difficult to assess the significance of this situation later in the flight.

The flight line assessment is an excellent opportunity to introduce yourself to the patient and to allay any fears about flying. This dialog is an excellent baseline assessment of sensorium and mentation. Vague changes in the patient's sensorium or mentation during the flight has a number of implications including: hypoxia, increasing intercranial pressure, or worsening perfusion deficits.

Onloading/offloading patients

The flight crew should direct all onloading and offloading activities. All IV's, tubes, wires, traction devices, etc. must be secured. A number of options are available for getting the patient through the narrow door of the aircraft. A scoop stretcher with appropriate straps is probably the most effective means of getting a nonambulatory patient onboard. Scoop stretchers are difficult to use on obese patients, though. They also require a great deal of manipulation in the ambulance and aircraft. Folding stretchers, Reeves stretchers, and backboards can be used in some aircraft but they can be awkward and it is often difficult to make the bend from the door to the stretcher without tilting the stretcher sideways. A folding nylon stretcher sheet can be used as an alternative and is particularly effective for light weight patients. It rolls like a sheet and can be easily placed under the patient. It can be left under the patient inflight to help with turning and positioning. Regular linens should never be used to load patients because of the danger of tearing and potential for dropping the patient.

To onload/offload the patient into the aircraft, all ground personnel should remain outside and the flight crew should position themselves in the cabin. The ambulance stretcher should be brought as close to the aircraft as possible. In extremely cold or hot environments do not prolong patient exposure to the elements. If it is raining on the flight line, use an umbrella to shield the patient. Talk through all steps of the loading process with the ground ambulance crew since they may be unfamiliar with the techniques. The ground crew should remain outside the aircraft and "hand-off" the patient into the aircraft. The flight crew can manipulate the patient as needed inside. Be careful about how much weight the aircraft stairs can bare. Most aircraft doors with integral stairs have a weight limit of 250 pounds or less. Too much weight could damage the door and disable the airplane.

Once situated in the aircraft, reassess all lines and tubes. Be especially careful with chest tubes and artificial airways. Make sure that all medicines, charts, luggage, and belongings are onboard. Secure the patient and passengers. Have all medical equipment at hand in the event they may be needed during takeoff.

Stowage of luggage

Most patients and passengers will have luggage for the flight. It is important to properly stow these in either the outboard lockers of the plane or inside the cabin. Outside lockers are usually nonpressurized and are subject to freezing and pressure changes. An example of this is a recent flight of Citation jet from Houston to Charlotte. The flight crew received some fresh Texas beef as a promotion effort from the FBO [fixed base operator]. The meat was placed in the nose locker and on arrival in Charlotte they were found to be frozen solid.

Any medicines or personal items which will be needed during flight should be carried in the cabin but cabin luggage should be kept to a minimum whenever possible. During turbulence or rapid decompression, any loose item inside the cabin could become a projectile. Make sure that ALL personal belongings are loaded. It will be inconvenient to ship missed items home after the flight. When offloading, make sure all luggage and personal items go with the patient and passengers.

Passenger briefing

Federal Aviation Regulations require that all passengers be briefed on emergency exits, aircraft equipment, and emergency procedures. Prior to onloading, explain to the patient what he/she will encounter. Explain to the patient and passengers how to open doors and point out the emergency exit(s) and their operation. Emergency oxygen systems [if installed] will vary between aircraft and each flight crew member must be familiar with their operation. Emergency oxygen systems should be explained during the normal preflight briefing. Describe normal takeoff procedures and possibility of turbulence. For first time flyers, the dynamics of takeoff can be terrifying if not explained ahead of time. Seat belts should be secured and remain in place for the duration of the trip. Additional information regarding flight time, enroute fuel stopovers, and aircraft speed and altitude can be offered. Patients and passengers may have questions about the trip and these should be answered. Much of the fear of flying can be alleviated by a comprehensive briefing before takeoff.

Takeoffs, landings, and cruising at altitude

Many of the problems encountered during flight occur during takeoff and landing. Pressure changes and their implication have been described previously. A study indicated that ear pathology in the form of hemorrhage and tympanic membrane rupture occurred with ascents/descents of 1000 ft/minute. Therefore flight profiles which include slow ascents and descents (maximum of 500 ft./min) are indicated for air ambulance flights. Pressurized airplanes will have little problem with this since changes in cabin altitude is related to the pressurization system. Yet in nonpressurized aircraft the change in cabin altitude is directly related to the aircraft's change in altitude. Therefore pilots should be more cautious in nonpressurized airplanes when planning altitude changes.

The flight crew should be especially observant during the early part of the flight. Vital signs should be taken often and the patient should be reassessed frequently during climb and at altitude. IV fluids will be difficult to regulate during this time if they are gravity fed. Keep an eye on flow rates and use an infusion pump if possible.

Avoid moving about in the cabin. Sudden movement to the rear or front of the plane can shift the airplane's center of gravity. This could pose a serious safety hazard. Always remain seated during takeoff and landing. If you must move about during level flight do so slowly and make no abrupt movements forward or aft. Keep tables stowed for takeoff and landing. Do not serve beverages or meals during the immediate takeoff and climb phase. These should be held until clear of all clouds and the aircraft is in level flight. Begin preparation for landing during initial descent from altitude. Stow all tables, reassess the patient, and watch for changes in IV flow rates. Ear and sinus blocks are more common on descent so it will be a good idea to reinforce methods on how to clear the ears. Chewing gum on descent for adults and feeding infants with a bottle is a good method of preventing ear/sinus blocks.

Aeromedical Flight Profiles:

- Slow ascents and descents;
- Direct routing wherever practical and safe;
- Avoid turbulence;

- Minimize ground time;
- Plan for enroute alternates if a medical emergency should arise during the flight;
- In marginal weather, consider the problems of not getting into a particular airport. Plan for contingencies such a using the alternate airport and the possibility of getting ground ambulance transfer;
- File Lifeguard flight plans when priority handling is needed. Routine use of the Lifeguard callsign should be avoided if preferential routing is not needed;
- Refuel with a patient onboard should be conducted only when emergency equipment and personnel are available and ready to evacuate the aircraft if needed.

Nutrition

Nutritional needs must be addressed for all flights. For short trips, a small snack and beverage will help alleviate hunger rather that supply adequate calories for daily needs. Large lunches should be avoided, especially during turbulent flight due to the possibility of motion sickness. On longer flights however, meals will be an important source of nutrition and hydration.

Diabetic patients present a special problem. Dietary intake must continue on a rigid schedule per the patient's normal routine. On long flights, attention must be paid to time zone changes. For example, a seven hour flight from North Carolina to California may land at 9 PM Eastern time but will actually be 6 PM local California time. Meals should not be rescheduled. Insulin and all other medicines should be given according to their original time zone.

Gastric feedings will also present a problem. On short flights feedings may be held because of the danger of gastric reflux during handling and turbulence. On longer flights gastric feedings will be an important source of hydration and nutrition. Hold tube feedings 1/2 hour before and after takeoff and landing.

Termination of Flight

The final landing of the day obligates the crew to prepare the aircraft for its next mission. All garbage should removed and the patient compartment disinfected with a suitable agent. Oxygen tanks should be changed if below 500 psi. Battery operated equipment should be recharged. Dirty linens should be stored in an appropriate place. Infected linens should be double bagged and appropriately labelled. Flight kits and drug boxes should be replenished. In hot or cold environments remove any equipment which may be sensitive to temperature extremes such as drugs, IV solutions, plastic catheters, Nicad batteries, and so forth. It may be handy to have a small cart to move equipment and supplies to and from the aircraft.

The aircraft should always be ready for an unexpected mission or emergency flight. Know before hand how much oxygen will be needed. Expect that a deadhead leg will result in another mission. Have enough equipment, supplies, and linens to accommodate an additional patient. Always BE PREPARED and keep all flight equipment in top working order.

Care and Feeding of Aeromedical Equipment

Aviation oxygen [yellow bottle] is dry and should not be used or routine patient administration. Medical oxygen [green bottle] contains moisture which can freeze. Do not store medical oxygen bottles in exterior nonpressurized storage lockers because of this problem of freezing. Never use petroleum products such as Vaseline jelly for lubrication on oxygen fittings or equipment. This can cause rapid oxidation, fire, or explosion. A recent fire and destruction of an aeromedical helicopter is thought to have been caused by grease coming in contact with the medical oxygen system. Patients should remove lipstick and makeup from around the face when receiving supplemental oxygen since these petroleum based products can produce burns to the lips and skin. As stated previously, make sure that adequate oxygen is available for the trip. Always have enough cylinders to manage an emergency and plan for contingencies such as delayed landing due to weather.

Intravenous therapy will pose some peculiar problems during flight. Avoid using bottles whenever possible. The rigid glass container can not expand as altitude is gained. At the very least, this will cause a back flow of IV solution through the venting port. The glass bottle is also prone to cracking and on rare occasion may explode [for example during rapid decompression at high altitude]. Intravenous hyperalimentation may present problems since these bottles are specially mixed and are usually not available in plastic containers. If a TPN bottle must be carried, place the container in a plastic garbage bag and wrap it with tape [to contain an explosion]. A syringe must be placed on the vent port to compensate for pressure differentials and prevent the dripping of IV fluid.

Pressure changes will make IV's run erratic and an IV bag may not be able to be lifted high enough to assure gravity feeding. Infusion pumps or flow devices should be used on all continuous IV's. In lieu of an infusion pump, the IV bag may be placed in a pressure bag or a spare blood pressure cuff may be used. Time tape all IV solutions even for short trips. Flight crews must be vigilant for air bubbles in the IV line. These pressure devices can force a significant amount of air into the venous circulation and cause an air embolus. All IV connections should be checked for tightness prior to onloading and IV sites should be viewed for local infiltration and patency. Have at least two patent intravenous lines for critical or potentially unstable patients. Expect that an IV will be pulled out during the flight [Murphy's Law]. Most infusion pumps are reliable and accurate. Yet the crew should never become complacent with its equipment. Transport pumps must be battery operated and be small enough not to interfere with loading and patient care inside the cabin. The IMED pump is quite common in the hospital environment but it is rather large and heavy and requires a special IV cassette. Smaller infusion pumps have been designed specifically for transport such as the MTP pump. This pump uses special IV tubing and can cost from $1,900 to 2,400 per unit. Yet for advanced life support transfers these types of devices are essential. Know the battery life of each particular pump the team uses. An inverter may be needed on long flights to augment battery operated equipment. Any battery operated equipment should be fully charged and backup batteries [if available] carried along. Nonfunctioning equipment at altitude due to poor batteries can be a grave problem. Nicad batteries loose effectiveness in extreme cold. During the winter months, battery operated equipment should be kept warm, for example cold LifePack batteries can be warmed in pants pockets.

Defibrillation has been shown to be safe and effective in the aeromedical environment. Dedrick carried out multiple defibrillation attempts in an aeromedical helicopter without incident. Airborne defibrillation, like ground defibrillation, should be conducted by trained ACLS personnel. The danger of shock to aeromedical crew members is always present when using improper technique.

Drugs and IV fluid may be effected by extreme heat and cold. Drugs such as Insulin, Dobutamine, and Nitroglycerine will loose potency when exposed to heat. Cold will crystallize Mannitol and subfreezing temperatures will form ice in IV solutions. Cold will also make plastic IV tubing brittle and subject to cracking. Flight bags should be removed from the aircraft and protected from extreme heat or cold.

Narcotics and controlled substances present a special problem. Security of the drugs from tampering is essential. Yet many fixed-wing flight programs do not have 24 hour personnel in attendance. Small lock boxes may be installed on each aircraft to carry the drugs. As an alternative, each flight nurse may carry individual packets of controlled substances and be accountable for them. Each organization must inquire about licensing from the Drug Enforcement Agency [DEA] and appropriate state agency if controlled substances are kept on premises. Any electrical or electronic

Equipment can emit spurious electrical impulses and interfere with the aircraft's navigation and radio system. This can be especially hazardous in during poor weather conditions. An excellent resource on acceptability of equipment for aeromedical transport is the U.S. Air Force. The School of Aerospace Medicine extensively tests equipment which may be used in an aeromedical environment. Reports are issued every two years and are released to the general public through the National Technical Information Service.

Case Studies

Case Study #1.

Synopsis:

Patient is a thirty year old male, closed head injury from a truck accident six weeks ago. Patient had no prior medical history before the accident. He is being transported from a regional hospital home to Texas where he will be placed in a rehab facility.

Trip length 700 miles,

Minimum Enroute Altitude 6,000 ft.

NEURO: S/P Craniotomy for subdural hematoma seven weeks ago, had two seizures postop but now on Dilantin and no recent seizure activity, purposeful to pain but does not follow commands. Agitated at times with stimulation.

RESPIRATORY: Currently on 30% humidified oxygen via #8.0mm Shiley Trach, most recent arterial blood gasses [ABG's] 7.42-34-75 Sat 95%, treated for Pseudomonas Pneumonia, on IV antibiotics, requires frequent suctioning.

Chest XRay - resolving left lower lobe Pneumonia.

CARDIOVASCULAR: stable, B.P. ranging 130 - 170/70 - 80, HR 60-90, no murmur, EKG = Sinus tach, pulses all palpable.

GI/GU: Abdomen soft, nondistended, gastrostomy tube is infusing Osmolyte at 60cc/hr, minimal residuals, had recent bout with diarrhea but resolving with Immodium, Foley catheter - recent E. Coli urinary tract infection is being treated with Septra.

MUSCULOSKELETAL: Mild contractures to upper and lower extremities, left lower extremity casted [cast five weeks old] for Tib/fib fracture, good perfusion to extremity, small Saccral decubiti being treated with Duoderm.

IV's: D5W to peripheral R. forearm at KVO.

MEDS: Dilantin, Reglan, MVI, Septra, all per gastrostomy tube, Primaxin IV Q8 hrs, Valium and Immodium PRN.

LABS: ABG's as above, H/H 11.4/31.2 WBC 14.2, Na 138 K 3.9 Glucose 145 [all from last week].

Major Transport Considerations:

- Prevent further hypoxia, monitor oxygen saturation with pulse oximeter during transport and maintain above 95%;
- Pressure changes will affect tracheal cuff, must be adjusted with cabin altitude;
- dehydration of the airway is possible, place a humidivent over the trach and add a few drops of distilled water directly into trach every 30-45 minutes to prevent plugging and airway drying;
- Gastric reflux during handling and/or turbulence could possibly cause aspiration even with trach, hold tube feedings two hours before transport and aspirate residual, monitor blood glucose with Dextrostix;
- Have adequate suction and backup, make sure all equipment if fully charged for flight, assure that adequate oxygen is onboard and consider enough for contingencies;
- It is imperative that IV antibiotic is continued on schedule, make sure that hospital sends along scheduled dose, consider changing IV to heparin well to facilitate transport but hydration may be a concern if the trip is very long [over three - four hours];
- Seizures may be precipitated by aircraft vibration, consider the possibility of inflight seizures, make sure that pilot knows about the importance of keeping props in synch to minimize vibration, have anti-seizure meds in drug kit as well as appropriate airway/ventilating equipment.

Transport Highlights:

This patient was transported in a nonpressurized Piper Navajo. Tube feedings were held and glucose was normal. On takeoff, patient starting having a coughing spasm [probably from the trach cuff enlarging] and frequent suctioning was required the first half of the trip. Also noted was some abdominal distension which resolved with aspirating Gastrosomy tube [aproximately 100cc air removed]. No further problems enroute, maximum enroute altitude 6,000 feet. Oxygen titrated with pulse oximeter to maintain 95-96%.

Case Study #2

Synopsis:

Patient is a fifty two year old white male, history of end stage COPD, on continuous home oxygen, was visiting daughter in Alabama and developed pneumonia, now on ventilator, attempts to wean over past two weeks unsuccessful, patient wants to be transferred home to South Carolina for long term ventilator care [last year he was on the vent. for two months].

Trip length 450 miles

Minimum Enroute Altitude 2,000 ft.

NEURO: Awake, alert, oriented, appropriate to commands and questions, no focal deficits;

RESPIRATORY: Mechanically Assisted Ventilations [MAV], 30%, Vt 800, IMV 6, no PEEP, ABG's 7.46-36-88 Sat 96%, has finished a ten day course of IV antibiotics for RML pneumonia, infrequent suctioning,

Chest XRay -Increased hilar density and consolidation RML.

CARDIOVASCULAR: stable, B.P. ranging 110 - 130/60 - 70, HR 80-130, no murmur, EKG = Atrial Fibrillation with rare PVC's, no acute changes, old inferior wall MI, pulses all palpable.

SYSTEM = GI/GU: Abdomen soft, nondistended, Dobhoff tube for meds and tube feeding, minimal residuals, Pt. Voids.

MUSCULOSKELETAL: Has been getting up to stretcher chair twice daily without problem,

IV's: Heparin Well,

MEDS: Lanoxin, Xanax, Reglan, Persantine, Inline treatments with Albuterol Q6hrs, Decadron, Tagamet, Theodur, Lasix, all meds per dobhoff,

LABS: ABG's as above, H/H 10.2/30.1 WBC 9.4, Na 134 K 3.0, Glucose 224, Dig 1.1, Theophylline 18.2.

Major Transport Considerations:

- Ventilator management - maintain current saturation throughout flight, transport with volume ventilator is preferred, RT and RN crew necessary; Pressure changes will affect tracheal cuff, must be adjusted with cabin altitude;
- Gastric reflux during handling and/or turbulence could possibly cause aspiration, hold tube feedings two hours before transport and aspirate residual, monitor blood glucose with Dextrostix;
- Have adequate suction and backup, make sure all equipment is fully charged for flight, assure that adequate oxygen is onboard and consider enough for contingencies, be ready to reintubate patient if ETT becomes dislodged;

- Continue current meds, consider having potassium replaced prior to flight, consider IV valium prior to transport for sedation;
- Continuous cardiac monitoring mandatory, ACLS drugs must be available.

Transport Highlights:

This patient was transported in a Piper Navajo without problem. The case was thoroughly reviewed by the Medical Director and he found no problem with transporting this patient in a nonpressurized environment as long as the trip could be conducted at 4,000 feet or below. Since the flight was conducted in late fall, there was little problem with convective turbulence and the actual flight was very smooth. The patient's main problem is mechanical ventilation rather than oxygenation. Cost was a factor here and the family could not afford the quoted price of a pressurized turboprop. The patient received 5mg IV Valium when we picked him up at the referring hospital and he did well throught the transport. Oxygen was maintained with pulse oximeter to baseline values. A smaller nonpressurized twin [such as the Beech Baron or Piper Seneca] was ruled out due to concerns of the small cabin.

Case Study #3

Synopsis:

Patient is a forty year old male, C2-C3 subluxation with resulting paralysis from auto accident five days ago, patient is in a halo vest, ventilator dependent, and weighs 350 lbs! Being transported to a regional spinal cord facility aproximately 375 miles away.

Minimum Enroute Cabin Altitude 6,000 ft. Aircraft maxiumum cruise altituted: 24,000 feet

NEURO: Patient is awake and responds to simple commands but is confused to time and events, head CT negative but MD suspects mild closed head injury, Halo vest, only gross upper extremity motor movement,

RESPIRATORY: MAV, 70% FI02, Vt 800, PEEP 12, A/C 18, #7.0 Shiley trach, AM gasses: 7.32-32-63, Sat 91%, gets dusky with suctioning,

CXR bilateral lower lobe infiltrates, no pneumothorax,

CARDIOVASCULAR: EKG Sinus tach 120-150/min, nonspecific ST changes, no prior cardiac history, BP 90-110/50-60 [arterial line] on dopamine 4-7ug/kg/min, pulses palpable, temp spikes to 103,

GI/GU: Abdomen slightly distended, tube feedings on hold, NG to Gomco - small amt of blood returning, Foley catheter,

MUSCULOSKELETAL: Cast to RLE - ankle fracture,

IV's: 3-lumen R Sublcavian,

MEDS: Decadron, Tagamet, Ancef IV, Demerol PRN, Inline Albuterol, Aminophylline @ 40mg/hr, Dopamine as above.

LABS: ABG's as above, H/H 8.4/24.7 WBC 22.5, Na 148 K 3.3 Glucose 340, Staph grew from sputum culture, Blood cultures negative.

Major Transport Considerations:

- Prevent further hypoxia, this patient may not tolerate even a small increase in altitude, he is also being underventilated, full volume vent with PEEP valve mandatory, as well as adequate suction/oxygen as outlined previously, maximize ventilations prior to transport;
- Pressure changes will affect tracheal cuff, must be adjusted with cabin altitude;
- Anemia should preferably be corrected prior to transport, have medical director suggest transfusion;
- Dopamine and Aminophylline drips may present a problem in-transit, have adequate infusion pumps for transport, assure that batteries are fully charged;
- Weight of patient and Halo vest make onloading and offloading patient extremely hazardous, considure having extra EMS personnel accompany flight crew to/from airport, give serious consideration to type of aircraft and ease of loading, for example, a King Air may present some very serious problems;
- A pressurized aircraft and minimum cabin increase is mandatory;
- Make sure that hospital sends along a wrench to dismantle the Haloin the event of a forced landing and possible aircraft evacuation.

Transport Highlights

The patient was flown in a Lear 24 jet with an RN and RT crew. The patient was placed on an eggcrate mattress then a scoop stretcher for rigid immobilization. Loading was difficult but the large cargo door of the Lear Jet made it safe [the flight crew agreed that loading this patient into a Beech King Air would have been dangerous]. During initial climb out, the patient suddenly dropped his sat below 90% [cabin was climbing @ 2,000 feet]. The pilot stopped climb, patient was bagged and suctioned and placed on 100% oxygen. Several mucus plugs were suctioned and the patients respiratory status improved. The patient tolerated the rest of flight without problem.

Aircraft Emergencies

Physiological and pathological considerations of aeromedical transport have been discussed. The focus of air evacuation is the airplane and the environment in which it flies. As a flight crew member you will be responsible for passenger and patient safety. The concepts of aviation may be unfamiliar to you and the emergencies that can arise will require different strategies.

What follows is a discussion of the pertinent emergency conditions that a flight crew may face. It must be stressed that these are rare occurrences yet the crew must be ready to respond to an inflight emergency at any time. This manuscript provides a general overview of these emergency conditions and every member of the flight team must practice these techniques under simulated conditions. Take time some day to practise emergency evacuation or familiarize yourself with the location of fire equipment and essential aircraft systems. You might also consider attending a survival course to supplement the overview which follows.

Facing an inflight emergency is as much a state of mind as it is definitive action. The true professional will face the unknown with confidence and competence. Panic during a problem may make a correctable and survivable incident even more difficult. Lastly, are you prepared mentally and physically to respond to an emergency. Take a close look at your capabilities before you have to face a difficult situation. The Boy Scout motto it noteworthy, BE PREPARED.

Loss of Pressurization

The pressurized aircraft cabin is prone to leakage. A great deal of stress exists between the higher pressure cabin and the outside atmosphere. Two problems emerge. Slow leaks may produce a less than optimum cabin environment. If the leak goes unnoticed, the crew and patient may be exposed to an oxygen starved environment. On the other hand, loss of a window or door can produce sudden and dramatic changes. Both of these are real emergencies yet present in different ways.

Gradual pressurization loss

Loss of internal pressurization may be insidious. This can occur because of leaks in the door or other pressure seals. Unless an internal altimeter is visible to the flight crew, signs of hypoxia may occur gradually and go unnoticed. The placement of an internal altimeter in plain view of the aeromedical crew is strongly recommended. A standard aircraft altimeter or inexpensive auto altimeter can serve this purpose well. The crew can recognize changes in internal cabin altitude and react accordingly. If gradual cabin depressurization is suspected, don an oxygen mask immediately. Assist the patient and passengers as soon as feasible. Know your own personal signs of hypoxia and never assume that giddyness, loss of concentration, or lassitude is related to fatigue.

Rapid decompression

The rapid decompression of a pressurized airplane is dramatic and unmistakable. It usually occurs with a lost window or cabin door. The time to equalize the pressures between the cabin and external environment is dependent on the altitude of the aircraft and size of the hull rupture. For example, loss of a window will take 30 seconds to equalize cabin pressure at 25,000 feet. At 40,000 feet it will take approximately 50 seconds. Loss of a door will cause a more rapid pressure equalization for similar altitudes. The following will occur in rapid succession during rapid decompression:

- A roaring noise will be heard and wind will rush into the cabin;
- Debris will move rapidly through the cabin toward the lost door or window. Any person sitting near the source of decompression may be sucked out of the plane if not belted in their seat;
- Fogging and misting of the interior will occur due to condensation of water vapor in the cabin.
- Moderate to severe cold will follow, exposing passengers and crew to frostbite and hypothermia. Outside temperature may be as low as minus 30 degrees.
- The sudden pressure shifts will cause gas expansion such as abdominal distension. Dysbarism is possible at high altitudes.

The crew members must react immediately to this emergency:

- Quickly don an oxygen mask on yourself and then ensure that all other crew members and passengers have oxygen. Time of useful consciousness [TUC] during a rapid decompression at 30,000 ft is approximately one minute and at an altitude of 45,000 ft TUC is only 13-16 seconds. An unconscious crew member is of no use to passengers or patient(s).
- Hold on to your seat or a stable portion of the aircraft, the pilot will place the aircraft into a steep bank and dive to decrease altitude as rapidly as possible. This is another reason why seat belts should be worn at all times.

- Patients already on supplemental oxygen should be given 100% O_2. Ventilators may become erratic or inoperative during decompression and manual bagging, when feasible, is necessary to guarantee proper oxygenation during the emergency.
- Protect passengers, patients, and crew from the cold. Offer blankets as available. The pilot will give maximum cabin heating when he is able.
- Give any immediate first aid but delay tending to minor cuts and bruises until the emergency is completed. The pilot will land at the nearest suitable airport. Prepare for a precautionary forced landing.

The severity of the pressurization emergency will be dependent on how fast pressure is lost to the outside altitude. Jet aircraft operating at altitudes of 35,000 feet are at greater risk than smaller piston prop aircraft travelling at 14,000 feet. This should be considered when deciding on a particular aircraft to use for aeromedical transport. For example, a critical patient may not survive a rapid decompression at jet altitudes but may be unharmed at lower piston-prop altitudes.

Onboard Fire

An inflight fire an emergency of the highest order. Because of the unpredictable nature of the location of fires and the possibility of succumbing to toxic fumes, any slight odors, wisps of smoke, or any suggestion that there is a fire onboard the aircraft should be brought to the immediate attention of the pilot. There are three primary sources of onboard fires: engines, electrical equipment or wiring, and careless use of matches or cigarettes. If a fire is discovered, the flight crew should make every attempted to contain or eliminate the fire. Fire extinguishers are mandatory on all civil aircraft and the crew should be familiar with their operation. Fire equipment should be checked during preflight.

Should an emergency be called, the pilot will descend and land as rapidly as possible. This can also produce some unusual aircraft attitudes. Any passengers should be briefed and equipment and personnel should remain secured until the aircraft is safely on the ground. Evacuation of the plane is the same as with emergency landings described below. Smoking is prohibited within 10 feet of an oxygen cylinder per Federal Aviation Regulation 135.91. It is common sense that smoking should banned in the presence of a patient. In small cabins, smoking is annoying and potentially hazardous to passengers and crews. All air ambulance organizations should consider writing policies banning smoking onboard its aircraft.

Turbulence and Poor Weather

Weather can pose a number of hazards. During the summer months, thundershowers can form and may cause turbulence or diversion of the flight. Thunderstorms are violent entities and no aircraft can electively fly through them with hopes of survival. Lightening is also a byproduct of intense thunderstorm activity. Airplanes are insulated from the ground, therefore a direct lightening hit does not usually pose an electrical hazard to the crew. Yet lightening may disrupt normal aircraft systems especially radios and cause an inflight emergency due to loss of aircraft systems or power. Hot humid weather will also increase the density altitude. For example a 90 degree day could raise the relative altitude of the airport a few thousand feet thereby degrading aircraft performance. This may significantly increase takeoff and landing distance. When planning an aeromedical flight during the summer, work closely with the pilot to determine whether a particular airport has adequate runway length. In a cold and dry environment, aircraft performance improves and will give better short field capabilities.

Winter travel brings a totally new set of problems. Weather patterns during late fall, winter, and early spring can bring prolonged low cloud ceilings, ice, and snow. Low cloud ceilings are particularly troublesome in marginal weather because of the difficulty in landing at a particular airport. Instrument guidance is available at most airfields. Yet the ability to land at any particular airport will depend on the lowest cloud ceiling and visibility at the time of landing. Minimum landing requirements will vary. Some instrument approaches may have minimum cloud ceilings of 1,000 feet or more. On the other hand, precision instrument approaches at major airports may have minimums to 200 feet or less. During poor weather, it may be necessary to schedule flights into airports with precision instrument landing systems [ILS] even though they may be quite a distance away from the referring hospital. This will add extra time for ground transport which must be taken into consideration.

Icing and snow is also of major concern. Aircraft without anti-icing and deicing equipment may be at risk when travelling during the winter months. Ice buildup on the wings can prevent the aircraft from flying. Even aircraft which are certified for flight into know icing conditions should proceed cautiously. It may be wise to delay a flight when moderate to severe icing is forecast. Snow will decrease visibility and increase landing length. Snow on the ramp will also pose a hazard to flight crews, especially during onloading and offloading of a patient. Use extra care under these circumstances and limit exposure to the cold. Have extra blankets available during the winter months. Mylar or Space blankets are excellent protection from the elements and should be used to wrap patients prior to exposure to the elements.

Landing Emergencies

Most aircraft emergencies occur during takeoff and landing. One of the most common emergencies during this phase is landing gear failure. The problem may be simply a burned out gear indicator bulb. Yet there is always a possibility that the gear may be partially extended or stuck. This would result in landing gear collapse during landing. The pilot may make a number of abrupt maneuvers in an attempt to force the gear into a locked position. Several low passes may be attempted so that the control tower can look and see if the gear is in proper position. Precautionary or forced landings may also occur with engine failure or other mechanical difficulty. There are a few basic principles which are common to all landing emergencies. These are outline below:

- Brief the passengers and patient(s). Some of the abrupt airplane maneuvers can be frightening. Never become excited and make every attempt to convey that the situation is under control. Never lie that an emergency does not exist.
- Rebrief passengers and patients on emergency exits.

- Remove sharp objects from pockets such as pens, scissors, uniform pins, etc. These sharps can cause puncture wounds during the sudden deceleration forces of a crash. Attend to the patient:
- Remove spika casts because they could impede egress. This is the general reason why these casts should be bivalved;
- Patients on respirators should be transferred to a manual bag. Be sure that respirator and equipment is stowed and will not present an addition hazard if they became loose;
- Disconnect an isolette from the aircraft electrical system and transfer to battery power. Pad the infant inside the isolette with blankets and pillows. If the infant is stable and can survive outside the isolette, sandwich the infant between two pillows on your lap and secure with a second seat belt. Do not put the seatbelt around yourself and the infant. This procedure should also be used for small children. The safest seat in the aircraft is located facing rearward against a partition in the cabin [such as behind the pilot].
- Make sure that all equipment is stowed or secured. Remember, any loose item has the potential of becoming a lethal missile [such as a loose oxygen bottle];
- Loosen clothing, distribute blankets and pillows to act as padding;
- If overwater ditching is imminent, put life preservers on all passengers and patients. Do not inflate the life vest until successfully outside the aircraft since the inflated life vest will impede egress;
- Assume the brace position:
- .For sitting adults, place a pillow on the lap, then place head on knees. Make sure all seat belts are secure and snug. Raise feet and legs off floor and brace against a seat or bulkhead.
- Patients on the stretcher may sit in a seat if one is available and the patient's condition allows this. Have them assume the brace position.
- If a stretcher patient can not move, use extra padding especially towards the forward part of the aircraft. Make sure all belts are secure.

Crash Survival

Dhenin terms survival as: ". . . the actions and attitudes which help an individual to continue to live in spite of adverse circumstances, to improve his situation and to increase the probability of eventual rescue." A forced landing in a wilderness area or desert can produce some challenging circumstances. Two problem emerge. First is immediate post crash survival after forced landing. Second is survival in an inhospitable environment until rescue.

Immediate postcrash survival:

Lash describes five characteristics of crash survival: personality traits and character of the crew; the crash impact; the presence or absence of post impact fire; the severity of impact injuries; and lastly, the crash environment.

The personality traits of pilots have been closely examined. Aeromedical helicopters have had a disproportionate number of inflight crashes and the vast majority of these are related to pilot error. A number of aeromedical accidents have been conducted in environmental conditions which were imprudent. This holds true for fixed-wing transport as well. There has been much said regarding the mind set and perspective of air ambulance crews performing under emergency conditions. Although there is a great sense of urgency in transporting a critically ill adult or child to proper medical care, common sense should prevail. Flight at night, in poor weather, low visibility, or icing conditions will place the crew and aircraft in a more precarious situation. Risks and benefits of air transport should be carefully weighed and clear policy guidelines written which will prevent launching or continuing a mission in deteriorating conditions. Crash survival in this instance occurs before a flight is dispatched.

Immediate survival during the crash evolution will depend on the forces of impact, structural integrity of the aircraft, deceleration forces, and fire. The crew should maximize survival potential by following the precrash emergency procedures mentioned above. Additional items which will help survival include safety equipment such as helmets and protective clothing. In a fixed-wing environment it may be impractical if not intimidating to wear helmets. But a lot can be said about helicopter crews wearing helmets. They have the additional advantage of noise attenuation. Nomex flight suits provide significant protection against post crash fire. Yet nomex is expensive and unusually warm. Nylon and synthetic material will melt during exposure to high temperatures so these should not be worn. Wool or 100% cotton materials are the second best choice for uniforms, and flight clothing. Nylon hose and underwear is particularly hazardous and disfiguring from a post crash fire.

After the aircraft has stopped, exit the plane as soon as possible. Do not forget to use the emergency exit(s). Stretcher bound patients may be particularly difficult to remove from the aircraft. Any method to remove the patient will be appropriate. Concerns over spinal injury have little significance in the face of a post crash fire or possible explosion. Egress procedures should be practised by all aeromedical crews until they can be performed by rote. You should exit the aircraft with what you have on your body and stay a safe distance from the crash site. Never go back into the fuselage to get a medical bag or survival kit until the danger of fire or explosion has passed.

The most effective means of surviving a crash is to avoid one altogether.

Basic survival principles:

Survival in an inhospitable environment follows the "Rule of Threes". You can survive:

- three minutes without air;
- three hours without shelter in extreme conditions;
- three days without water;
- three weeks without food.

After egress, immediate survival priorities include protection from the environment, then rapid location and rescue. Finding water is a later concern if rescue is not expected in a reasonable time period. If there is no danger of fire or explosion, the aircraft's fuselage may make an excellent temporary shelter if it is still intact. Yet the radiant characteristics of the aircraft's skin may make the fuselage colder than its external environment. If fuel has contaminated the crash site, a decision must be made to stay and risk an explosion or to move away from the crash site to safer surroundings. In cold environments, building a shelter has the highest priority in order to prevent hypothermia and frostbite. Consideration should be given to the energy expenditure needed to build a shelter. Building a snow cave or cutting branches may take several hours, expel a great deal of energy, and expose the crew to hypothermia and frostbite. On the other hand multiple Mylar (space) blankets could be strung together to make a shelter in a few minutes.

Building a fire has a number of advantages over and above providing warmth. A fire in darkness or smoke during the daylight can be seen for quite a distance by rescue workers. A fire also has the benefit of raising morale amongst survivors. Additional insulation from the cold can be provided by wrapping blankets, sheets, maps, rug mats, etc., around individuals. Even in the summer months, near freezing or below freezing temperatures can be reached at high elevation.

Another priority is improving the chance of rescue. If a crash has occurred in a heavily wooded area, try to find a clearing nearby and create a signal to aerial rescue observers. Attempt to create an unnatural scene which can be easily seen in the air. Odd colored clothing, odd pieces of metal, loose seats, etc., can give rescuers a visible cue. A decision must be made whether to stay at the crash site. If the flight was being conducted under instrument flight rules [IFR] air traffic control will have a reasonable idea where the crash occurred and Search and Rescue [SAR] teams will be immediately dispatched. The chances are good that a rescue effort will begun in a short period. If weather conditions preclude immediate SAR activities [such as fog, blowing snow, icing conditions, or low visibility] there may be a benefit to attempting to reach a road or nearby town if they were seen shortly before the crash. If you are uncertain whether there is a possibility of finding help by foot, remain with the aircraft. If the aircraft radio is still operative, do not make blind calls unless rescuersare heard on the channel or aircraft are heard circling above. The international distress frequency is 121.5 Mhz. The emergency locator transmitter [ELT] which is required on many but not all aircraft should be activated if not done automatically during the crash. All flight crews should know the location of the ELT on their particular aircraft. The ELT should be checked routinely for operation and battery strength. If the ELT is operative, a loud cyclic noise will be heard on the distress frequency (121.5). With the aid of modern satellites and rescue aircraft homing devices, this signal can be pinpointed to a few feet.

A last word on survival. Always be prepared. How many aeromedical crews think about having warm clothing on a hot July flight. How would you react if you suddenly found yourself in a survival situation? Set priorities and maximize the use of equipment on hand. For example, you might take oil from the engine crankcase to make a distinctive smoky fire. Consider putting together a small survival kit and carry it onboard each flight. Some items which should be included are:

Table 2. Basic Survival Pack

- small flashlight;
- pocket knife [Swiss Army knives make excellent survival tools];
- waterproof matches;
- flares; whistle;
- small candle;
- Mylar or space blankets;
- compass;
- candy or fruit bars, life savers;
- small role of twine or nylon rope.

Remember, survival is as much a state of mind as it is luck.

Legal Considerations

The potential for malpractice litigation against aeromedical crews and air ambulance organization is quite real. Even nonprofit organizations and volunteer flight crews are not immune. The notion that the Good Samaritin Law will protect you from being sued should be dispelled immediately. The Good Samaritin Laws were designed to protect naive bystanders when rendering aid in times of emergency. These laws do not prevent anyone from bringing litigation against another individual. Rather, these laws can be used as a defense in any court action against a naive bystander. Since the aeromedical crew is acting in a professional manner, they will be held to the same standards and scope of practice as any other air ambulance organization or health care institution. If legal action is taken against you, you will be judged on what a reasonable and prudent professional [flight nurse or flight medic] of similar training would have done under similar circumstances. Whether or not you were paid for your services as a crew member on a flight team is not relevant.

This brings into focus a number of concepts. Are you prepared to assume responsibility for a patient during an air ambulance flight? Do you have the necessary education and training to function in an aeromedical environment? Are you performing within your scope of practice as legally outlined under your state Nurse Practice Act or Emergency Medical Services legislation? Are you current with skills such as starting IV's, intubating, handling ventilator patients, etc.? Are you acting under medical control from your organization's medical director or chief flight surgeon? Taking orders from referring physicians, especially when they are from a different state may pose some complex legal question. Are you acting within the policies, procedures and protocols of your individual organization or agency?

These questions are explored, not to intimidate or discourage anyone from becoming an aeromedical crew member, but to give a broad understanding of the legal concepts which guide our actions. The intent of this manuscript is to furnish concepts involved in transporting a patient by air. These concepts provide a basis for a standard of care which is remarkably different from a hospital or ground emergency medical services [EMS] environment. This curriculum makes the assumption that basic nursing or paramedical training has been obtained and practical expertise in these professions can be demonstrated. The Aeromedical Flight Crew Manual builds on this expertise.

Accountability and Liability

Accountability is a legal principle which states that you are responsible for any action or inaction you may take. These actions are measured against established standards of care. The legal authority to act as an MD, RN, EMT-P, EMT, LPN, or PA comes from a licensing agency in each individual state. This agency will determine the scope of practice of that licensee. For example, an EMT-P may be able to perform intubation, insert chest tubes, and start IV's after taking a prescribed course and having individual performance validated by some testing mechanism. An EMT may be familiar with these techniques but if performed without authorization he/she would be operating outside of his/her scope of practice as legally defined by the state licensing agency. When acting as a member of an organization, that organization has the ultimate responsibility for actions taken by its members. Omission or failure to act in a particular circumstance which cause injury is called negligence. Performing an action or procedure which causes an injury or performing outside the legally defined scope of practice is called malpractice.

Liability as a legal concept, attempts to place responsibility for an action or event on a particular person or entity. A person or agency may be legally liable for an action or event even though a casual relationship exits with the injured party. An air ambulance organization incurs some liability by presenting itself to the general public, although the exposure may be minimal [Brimhall]. Most of the liability exposure revolves around the care of a patient during transport. Another interesting legal dilemma is the relationship between the medical crew and the aircraft operator [FAR Part 135]. Generally speaking, the pilot in command and ultimately the aircraft operator will bear the responsibility for an incident or accident involving the aviation aspects of a particular trip. But a separate medical organization may have some liability -especially if it has "deep pockets" [Pangia]. For example, a hospital may pressure an air taxi operator into flying in deteriorating weather conditions to transport a critically ill patient, "he'll die if we don't get him there". The hospital or medical organization may incur some liability if a crash results. A medical crew member may have specific liability for a particular mission. For example, say an air ambulance company accepts a trip to transfer a trauma patient with an untreated pneumothorax to a distant university hospital. The aircraft was an unpressurized Piper Navajo and a registered nurse with critical care experience accompanied the patient. The pilot climbed to 10,000 feet to clear some mountains and then was going to decent to 4,000 feet for the rest of the trip. While climbing over the mountains the patient complained of severe chest pain and difficulty breathing. The nurse noted cyanosis and severe respiratory distress and significant hypotension developed shortly afterward. She asked the pilot to land as soon as possible since the patient's condition was deteriorating. The aircraft landed at a small regional airport andwas taken to a community hospital. At the hospital, an emergency physician inserted a chest tube and intubated the patient. Yet the patient died two days later from multisystem failure and shock. This trip was performed with the best of intentions. Yet this does not excuse the organization's ignorance or responsibility to recognize limitations of patient transport in a nonpressurized aircraft. The nurse has incurred significant liability. If properly trained in aeromedical procedures, she should have realized the effects of gas expansion at that altitude and realized that the flight was certainly dangerous and should not have been carried out. The pneumothorax should have been treated prior to transport and a pressurized aircraft should have been selected for the mission. This hypothetical scenario is not presented to discourage organizations or individuals. It is meant to show the complex nature of aeromedical evacuation. Every organization and individual should realize the limitations as well as the potentials of air travel.

Charting and Documentation

Howell found documentation of inflight patient care of Oregon`s 18 air ambulance services to be seriously inadequate. The flight crew must document initial assessment and give evidence of ongoing assessment and care throughout a medevac transfer. The flight chart also provides an excellent quality assurance tool to verify that competent care is being given by the medical flight crews. The inflight documentation should include:

- History of illness or injury. Pertinent notation of the present circumstances leading to air medical transport as well as significant past medical history that may have an impact during the flight. A patient being transferred home one week after a myocardial infarction may also have a chronic lung history which will complicate the transfer and this should be documented. The chart should also state whether the patient has had problems with ear or sinus block or has a prior history of motion sickness.
- Initial assessment. Long narratives of the patient and his condition or head to toe assessments have been use to document patient assessment. A systems review, though, provides much clearer information and shows that the medical flight crew member is considering the aeromedical consequences of multiple body systems. Main considerations of a systems assessment address the neuro [central and peripheral], respiratory, cardiovascular, gastrointestinal [GI], renal [GU], and musculoskeletal subsystems. Specific consideration were addressed in a previous chapter.
- Items specific to aeromedical evacuation include: time of arrival and departure as well as airports used; name of ground ambulance; maximum cabin altitude; location of patient's medical records and belongings [state that these were given to a particular person and have that person sign for the patient and records]; any enroute problems such as turbulence, motion sickness, ear/sinus block, dysrhythmia, abdominal pain or distention, circulatory restriction or pain from casts, etc. Intake and output should be recorded as well as any medicines given during flight. Make sure to document which time zone was used since this can vary by a few hours.

A final word on documentation: if you had to go to court over a particular case, could you determine from your documentation what you did inflight, or more important, did you show an ongoing assessment of the patient and provide appropriate and competent care. The outcome of litigation brought against you could very well hinge on your notes during inflight care.

Enroute Death

Death is not necessarily an enroute emergency if it is expected in a terminal patient. Yet unexpected cardiac arrest should be attended to swiftly and an alternate landing considered.

Problems arise when death is allowed to occur by choice, i.e. the patient has a living will and written documentation for no resuscitative measures. These terminal patients present a legal dilemma because of the problem with jurisdiction over where and when a death has occurred. It is difficult to determine the county or state over which death occurred during flight. If the aircraft lands at the nearest field, does that county have jurisdiction? Should the aircraft continue on to its destination or return to it departure airport? There is no clear cut legal guidelines since each jurisdiction may have its own peculiarities regarding death of a person. From a practical standpoint, premorbid and terminal conditions should be evaluated carefully. A patient who is likely to die during flight may present impossible legal problems for the air ambulance organization. On the other hand, a very humane reason may exist for attempting the trip.

If there is any question regarding the validity of a no code status, then the flight crew is legally obligated to perform CPR. Family members who are present during the transfer may be under extreme anxiety or duress. Be open and honest with your dealings with the patient and family. If agreement has been reached for a no code status, then having immediate family members present at the time of death can be an important part of the grieving process. Assist the family with their grief and do not feel uncomfortable in expressing your own.

Crossing State & National Boundaries

It is difficult to know every state and national law regarding inflight patient care. Nursing and EMS boards have jurisdiction at the state level but EMS personnel may also have local accountability as well. A registered nurse will have fewer problems with reciprocity since the license is uniform from state to state. EMT's and paramedics may have tedious problems with ability to carry out certain invasive procedures even within their own state boundary. Scope of practice may also be an issue. A paramedic who administers a medicine he or she is not authorized to give, such as a routine antibiotic, may be at risk for practicing nursing or medicine without a license. Yet on the other hand, paramedics may have advanced life support skills which a registered nurse does not possess.

Crossing international boundaries may also be problematic. Nursing reciprocity is extended to all U.S. trust territories and Canada. Yet individual flights into a particular country must be evaluated on a case by case basis. Bringing narcotics across international boundaries may provide a much greater problem. Check with the U.S. Customs Office for guidance. Portable radio transmitters can also create some concern and in some countries it is a capital offense to bring in portable radio transceivers without permission.

Local customs and language will be barriers to patient care on international flights. Be very conscious that foreign nationals may have a different perspective about American flight crews. Be quiet and reserved and respect the culture of the host country. Be especially careful at foreign airports since these may be heavily guarded and intruders shot without warning if they happen to wander into restricted areas. Never cross an international boundary without adequate documentation. A valid passport is highly recommended even if one is not needed. Flight crews should stay together and the aircraft secured as best as possible. Do not advertise the fact that you are an air ambulance, this might invite theft of equipment and drugs.

Flight Crew Considerations

The stresses of the aeromedical environment will also impinge upon the flight crew. Noise, motion sickness, hypoxia, gas expansion, and fatigue will take its toll. The flight team must operate at peak performance in order to give optimal patient care. Obese or debilitated crew members may not be able to function in the small confines of the airplane. Loading and offloading patients requires strength and finesse. Smoking will enhance the effects of mild hypoxia and poor dental hygiene may cause pain due to altitude effects.

Minor ailments such as upper respiratory infections, otitis media, gastrointestinal upset, or minor sprains and aches can cause a great deal of discomfort and possible serious complications even in pressurized aircraft. Self medication should be avoided. Check with the organizations medical director for all health problems.

Professional attitude must also be addressed. How a flight crew member carries him/herself will reflect on the air ambulance organization. Sloppy dress or mannerisms may produce anxiety and doubt in patients or family members. Lack of coordination between crew members or outright conflict can not produce confidence in the ability of the team. It may even cast doubt on the eventual outcome of the flight. Training is paramount. Competency in aeromedical transfer is gained through both didactic and practical experiences. Education is an ongoing process and all flight team members must keep up with training needs and current trends in the industry. A.

The Stresses of Flight

Flight team members must be aware of the effects of flying and make personal adjustments as necessary.

- Avoid "gas forming" foods and beverages. Carbonated sodas can wreak havoc with your gastrointestional tract during flight due to gas expansion. Know which foods produce gastric discomfort and avoid them the day before and day of the flight. Any gastric discomfort on the ground will get worse at altitude.

- Do not chew gum on ascent. Air swallowed by normal chewing can cause abdominal distension and discomfort.
- For every cup of coffee consumed, the body looses 1 1/2 cups of water. Dehydration can be a significant problem on a hot summer day especially after being exposed to a long flight in a very dry environment. Coffee makes the problem worse. The quick transit time from stomach to bladder may also produce discomfort in the unwary crew member. During a stopover, never pass up a bathroom facility, you may have to wait a long time for your next chance.
- Contact lenses have a tendency to dry due to low humidity in the aircraft. Bring moisturizers and an extra pair of glasses.
- No flying within four days of giving blood.
- Dental hygiene is important for preventing aerodontalgia. Teeth and gums in poor disrepair may cause pain and discomfort.
- Tobacco is an obvious evil. It not only produces chronic health problems but will also enhance the effects of hypoxia at altitude. Cigarette smoking onboard the aircraft is not only rude to passengers and dangerous to patients but may also pose a significant safety hazard.
- Alcohol is another significant evil. Its impact on crew performance is real. Not only does a hangover decrease performance and critical judgement but it will also enhance the effects of hypoxia. The FAA uses an eight hour "bottle to throttle" policy for civilian pilots. Yet this may not be adequate for peak performance for air ambulance teams.Ideally, no alcohol should be consumed within 24 hours before a flight. It should not have to be stated that crews should not drink while on duty.
- Drug effects can be potentiated by the aeromedical environment. Even innocuous medicines such as antihistamines can create drowsiness and aspirin has a theoretical disadvantage of heightening the effects of hypoxia. All crew members should check with their flight surgeon or medical director prior to self administering any drug. Illicit drug use falls into the same category as drinking alcohol on duty. The implications and probable outcomes should not have to be stated.

"Pack Your Own Parachute"

Murphy's Law [no relationship to the gas laws] states that anything that can go wrong will. This applies to air ambulances as well. A short transfer from Pennsylvania to North Carolina can result in an aircraft maintenance problem and overnight stay. Would you have enough money and personal items to make an overnight stay a comfortable one? Do you have the necessary clothing, especially in the winter months to provide warmth? A flight from south to north can produce temperature extremes from the 70's to well below freezing during the winter. Rain gear may be needed for a trip to Tennessee even though it is a beautiful clear day in Texas! Do you have an extra pair of eye glasses? How about sunglasses? You might also consider bringing a small camera to document a flight over the Grand Canyon or seeing a movie star at an airport. Common sense is an appropriate word. Following is a list of concerns for flight crews.

- Winter: Have enough clothing for the most severe weather expected. This includes sweaters, jackets, hats, mittens, and so forth. Layering of clothing is much more effective since layers can be added or removed as needed. Avoid wearing long underwear because of the possibility of sweating while working hard to load a patient and then being exposed to the cold. Although nylon hose may provide extra warmth and comfort, any synthetic material may produce "melt down" burns during a crash. If possible wear cotton or wool garments.

- Summer: Be careful not to wear extra undergarments or heavy clothing which can not be easily removed. Again, layering is much more effective. Bring a waterproof wind breaker or poncho for unexpected rain. An umbrella should be kept in the aircraft for patient and passenger comfort during boarding and transfer. Use care when exposed to the sun. Temperatures on the asphalt can be much higher than expected. Avoid prolonged direct exposure to the sun as this can cause excessive sweating, dehydration, sunburn, and general malaise. A small baseball cap can protect the head and shade the sun very effectively.

- Toiletries: Each crew member should carry personal items in a small flight bag. Consider such items as: toothbrush and toothpaste, brushes, razor and shaving cream, "female items", lip balms, hand cream, deodorant, handiwipes [since the airplane will not have a sink and running water], tylenol, Neosynephrine nasal spray, chewing gum, and any other essential item which may be needed for an overnight stay.

- Money: Have enough pocket change for snacks and small meals. A credit card should be carried for emergencies and contingencies. Remember "Don't leave home without it".

- Food and drink: Bring small snacks and light beverages for the trip. A small chest with ice will be quite useful. Avoid carbonated beverages since they have a tendency for causing bloating. Gatorade is a very effective thirst quencher. In the summer months a great deal of sweat can be produced and potentially cause mild to moderate dehydration. Gatorade can replace lost water and minerals. Use discretion when carrying patients who are NPO and avoid eating in front of them.

- Identification: Drivers license, name badge or ID, passport. Passports are highly recommended for all crew members. Although usually only proof of citizenship such as a birth certificate is needed for adjacent countries.

A last word: being a member of an air evacuation team can be exciting and worthwhile. Its takes a certain degree of professionalism and training to be effective in this environment. Dangers do exist but exposure is a matter of reasonable care. If the dangers are addressed and common sense prevails, then air transfer presents some definite advantages over other methods of patient travel. The rewards are just as real. Bringing together a patient and his family or rushing a burned child to specialized burn center can be very worthwhile, indeed, life saving.

The skies are calling for those who dare take the challenge.

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