REVIEW ARTICLE

CURRENT CONCEPTS

International Aeromedical Evacuation

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Worldwide, when the needs of injured or ill patients exceed what local clinics and hospitals can provide, urgent evacuation by air to the nearest well-equipped medical facility becomes the key to preserving function and saving lives. The international aeromedical evacuation industry is expanding, in part because of two recent trends: increasing travel to regions where road trauma and infectious diseases are endemic but dependable medical care is unavailable and an increasing number of travelers who are predisposed to injury or illness by advancing age or underlying medical conditions.[1-7]

Nearly all international travelers, even those who are elderly or who have chronic conditions, are able to complete their trips successfully.[7,8] Fewer than 0.5% of travelers require medical evacuation.[9] However, when 1 to 2 billion people travel by air every year, even a small percentage of severe medical incidents translates into thousands of annual international aeromedical evacuations.[2]

CLINICAL CONSIDERATIONS

INDICATIONS

The health conditions that frequently require transport reflect the population risk factors of both the home countries of the travelers and of their destinations. For international evacuation, the most common conditions include neurologic and orthopedic sequelae of road trauma, acute coronary syndromes, infections unresponsive to available therapies, and complications of pregnancy[10-15] (Table 1). A more detailed list of indications has been compiled by the National Association of EMS [Emergency Medical Services] Physicians.[16] It was designed in response to controversy over the appropriate use of air medical transport in the United States, where scene-to-hospital evacuation is far more common than in developing nations.

DECISION TO EVACUATE

International aeromedical evacuation begins when an attending physician who is familiar with the local medical system determines that a patient's needs surpass available resources.[17,18] If the condition and the additional rigors of evacuation are survivable, prompt evacuation should then ensue. Cardiac, neurologic, orthopedic, surgically remediable, and obstetrical conditions are most likely to benefit from immediate evacuation.[10-14] Acute psychosis and tenuous conditions — such as florid pulmonary edema, alcohol withdrawal, and uncontrolled seizure — benefit little from relocation and are especially difficult to manage inside an airplane.[19] For these conditions, evacuation should be delayed.

The evacuation of patients whose conditions are less severe is indicated when they require hospitalization in facilities in which adherence to universal precautions is not dependable (e.g., where sinks and gloves are unavailable), hygiene is a low priority,

or the absence of expertise or special equipment (e.g., orthopedic hardware for larger patients) risks creating unnecessary complications that can be avoided by travel to a comprehensively staffed and stocked center. Because blood is not an export commodity in any country, the early transfer of a patient at risk of bleeding (e.g., from an ectopic pregnancy) to a facility with a replete and reliable blood bank can avert a tragedy. This is a special concern in sub-Saharan Africa, where the safety of blood supplies may be suspect, and in Southeast Asia, where Rh-phenotype blood is not always available.

Evacuation is also warranted when critical drugs are substandard, prone to being counterfeited, or unavailable owing to supply disruptions, government regulations, or practice standards. We have performed evacuations when intravenous acyclovir was unavailable owing to regulatory restrictions and for pain relief after major abdominal surgery when local standards preferred acetaminophen over opiates.

ARRANGING THE EVACUATION

After determining the need for transfer, attending physicians may refer patients to an international evacuation company that maintains a medical clinic in the same nation or region as the patient, notify a private international air ambulance service in the patient's home country, or contact an assistance company. The first two services favor the use of purpose-modified air ambulances. Regional evacuation companies own or lease aircraft that can be dispatched within hours. With trained staff, logistic expertise, and an existing network of receiving hospitals, such aircraft are the transfer method of choice when time is of the essence.

Private air ambulance companies can complete bedside-to-bedside retrievals of patients in any nation that will grant passage and in any location that has a secure runway. The aircraft that such companies operate are usually positioned in developed nations so that they are unavailable for immediate international transfers. Such services are useful when patients need highly specialized treatments, like organ transplantation, that are limited to a few global locations. Drawing on the resources of major medical centers, they can include staff from any medical specialty, though they most often travel with flight-trained nurses and paramedics.

Most medically distressed travelers rely on continental or global assistance companies to arrange travel to the nearest medical center.[20] Such companies employ medical directors who coordinate treatment and transport plans with the attending physician and those at receiving hospitals. Assistance companies are most likely to engage commercial airlines in aeromedical evacuation.

The benefits of the use of commercial aircraft include substantially lower costs, long flying ranges that decrease overall transfer time by eliminating refueling stops, and fewer takeoffs and landings that avoid the acceleration and deceleration forces that could worsen conditions such as spinal cord injuries. Outside the United States, most airlines will transfer patients unless such a service is likely to cause a flight diversion or pose a risk to

Table 1. Medical Conditions That May Require Aeromedical Evacuation.*

Acute neurologic, vascular, surgical, or cardiac emergencies requiring time-sensitive intervention
Critical conditions in patients with compromised hemodynamic or respiratory function
Critical conditions in obstetric patients whose time of transfer must be minimized to prevent complications in the patient or fetus
Critical conditions in neonatal or pediatric patients with compromised hemodynamic or respiratory function, metabolic acidosis more than 2 hours after delivery, sepsis, or meningitis
Electrolyte disturbances and toxic exposures requiring immediate lifesaving intervention
Organ failure requiring transplantation
Conditions requiring treatment in a hyperbaric-oxygen unit
Burns requiring treatment in a burn-treatment center
Any trauma that is potentially threatening to life or limb, including penetrating eye injuries

* Adapted from the *Air Medical Physician Handbook*.[15]

other passengers or to the aircraft itself. On the basis of travel-insurance claims, it appears that the majority of international aeromedical evacuations are accomplished with commercial aircraft. Experiences with the commercial-aircraft transport of patients who are undergoing mechanical ventilation while awaiting lung transplantation or who have fulminant hepatitis requiring liver transplantation have demonstrated the safety and technical feasibility of this approach.[21-23]

Airlines place stretcher-bound patients in the rear of the aircraft to facilitate loading and to minimize interference with the aircrew and other passengers. Stretchers are allocated six seats that are folded forward, a privacy curtain is drawn around the patient, and the medical evacuation team is assigned seats across the aisle from the patient. For long-haul flights with severely ill patients, a relief evacuation team may also be aboard. Some airlines permit access to aircraft electrical systems, whereas others specifically prohibit the use of such systems for medical equipment.[24] Aircrews typically allow temporary modifications to overhead bins for hanging intravenous bags and taping schedules or flow sheets.

American-based commercial airlines have curtailed services for acutely ill passengers, and some contracts of carriage specifically refuse to transport patients who are in stretchers or who cannot sit upright in a seat or follow safety instructions.[24-26] This reluctance to transfer patients has shunted much aeromedical traffic destined for the United States (and nearly all domestic evacuations) to private air ambulances and has reduced transport options for Americans overseas.

Patients are still evacuated to the nearest available facility that will meet their needs. An injured U.S. national in Central America could be transported directly to the United States, whereas in central China, a patient would be evacuated to a medical center in Asia and, after treatment and recuperation, returned to the United States. The last step, called aeromedical repatriation, is now more likely to involve an air ambulance.

STAFFING

There are no federal or international standards regarding the qualifications of the flight team. Primary care physicians from Western nations commonly perform international transfers because they are most represented in international health clinics and because they hold passports that allow access to nations where transfers terminate. We uniformly include physicians in international evacuation because of the severity of injury or illness in patients we transport and the likelihood of encountering additional medical risks and complications when retrieving a patient. Physicians are also uniquely effective in ad hoc negotiations with receiving physicians and civil authorities and in improvising solutions to bureaucratic logjams.[27]

EQUIPMENT

Evacuation equipment, medications, and power supplies are geared to the specific needs of each transport. Planning must ensure the availability of adequate oxygen and power. The consumption of both will dramatically increase if the condition of a patient who is being mechanically ventilated worsens. Unplanned weather and mechanical delays further deplete supplies. Backup oxygen tanks, electrical converters, and spare batteries can avoid disastrous supply disruptions[22,28] (Table 2).

PROBLEMS AND PITFALLS

The keys to successful aeromedical evacuation are planning for and responding to any deterioration in the condition that mandated urgent transport and to conditions induced by the aerospace environment. Contraindications to aeromedical evacuation have to be assessed relative to the risks of forgoing advanced treatment, but the impulse to "scoop and run" must be balanced against an evacuation's inherent hazards (Table 3).[29-32] The two major stresses that altitude exposure imposes on human beings are hypoxia and gas expansion in body cavities.[28] Physiological responses to either of these factors can be immediate and life-threatening.[33]

HYPOXIA

Hypoxia results when the amount and rate of oxygen diffusion across membrane surfaces decrease with ascent.[28,34] Cabin pressures in modern passenger aircraft are maintained at a level equivalent to that of 5000 to 8000 ft above sea level.[1,35] At this level, passengers without serious medical problems typically have an oxygen saturation of 94 to 95%, but in patients with poor perfusion levels, oxygen saturation can drop into the precarious range of the hemoglobin oxygen-saturation curve.[28,36-38]

Hypoxia can be preempted with supplemental

Table 2. Sample List of Equipment for Aeromedical Evacuation.

Stretcher	Nasogastric tubes
Mattress	Jaw wire cutter
Sheets, pillows, and towels	Intravenous needles and tubing
Earplugs for patient	Intravenous fluids in bags (not glass)
Electrocardiographic equipment	Infusion device (not dependent on gravity)
Blood-pressure monitors, including electronic monitor with liquid crystal display (LCD) screen	Intraosseous needles
Capnograph	Point-of-care laboratory kits
Pulse oximeter	Fetal Doppler monitor
Thermometers	Delivery kit
Defibrillator with pads	Neonatal resuscitation kit
External cardiac pacing device	Battery packs with spares
Cervical spine collars	Power inverter for use of aircraft power source
Fracture immobilizers (not air splints)	Satellite telephone
Portable oxygen with regulator	Nutrition and hydration supplies for patient and crew
Backup oxygen tanks	Survival gear
Airframe-compatible ventilator	Reference materials
Suction device with catheters and drainage-collection units	Medication kit with drugs for resuscitation, anxiety, airsickness, and condition-specific uses
Tubing with connections	Bandages and dressings
Bag–valve–mask systems	Wound-treatment kit
Nasal cannulae	Gloves
Continuous positive airway pressure systems	Small surgical kit
Intubation equipment	Cleaning and disinfection material
Endotracheal tubes	Bedpan, urinal, and emesis basin
Oropharyngeal airways	Sharps disposal system
Tracheotomy kit	Waste containers
Nebulizer	

oxygen, ventilation, preflight blood transfusion in patients with anemia, and low-altitude flight paths.[39] Patients with severe pulmonary disease have been safely flown for long distances at altitudes at which commercial aircraft are typically flown.[22,40] However, altitude-related concerns are most imposing close to the time of injury or illness. Therefore, many pulmonary conditions, including severe asthma exacerbations or flares in chronic obstructive pulmonary disease, should be treated in local hospitals, with evacuation deferred until the patient's condition has stabilized.[41]

Unlike pulmonary conditions, cardiac ischemia suggestive of impending infarct warrants rapid reversal at a specialized facility. Supplemental oxygen with continuous monitoring of response is critical to avoid altitude-induced hypoxia and further ischemia. Despite the high morbidity and mortality inherent in acute coronary syndromes, even patients with substantial acute coronary obstruction usually tolerate aeromedical evacuation well.[13-15,34]

GAS EXPANSION

Gas expansion accounts for the majority of contraindications to aeromedical travel. A change from sea level to 8000 ft of altitude will expand the volume of trapped gas by approximately 35%.[34] In vulnerable patients, this can provoke a tension pneumothorax, dehiscence of surgical wounds, intracranial hemorrhage, and irreversible ocular damage. Whereas hypoxia can be detected with pulse oximetry and mitigated with supplemental oxygen, the consequences of gas expansion are difficult to recognize and reverse aboard aircraft. Recent surgery and head and chest trauma impose the greatest risks.[42] On the ground, air retention may be overlooked when hemorrhage control or wound management absorbs clinical attention. Preflight checklists that prompt chest radiography and cranial examinations in all trauma patients may help prevent in-flight decompensation (Table 4).[43-45]

Altitude exposure intensifies diving-related decompression sickness and arterial gas embolism.[46]

Table 3. Contraindications to Aeromedical Evacuation.

Absolute contraindications
Unsafe flying conditions, as determined by pilot
Terminal condition of the patient
Acute infection or contamination in communicable phase of illness
Combative or uncontrollable status of the patient (i.e., a risk to aircraft or crew)
Relative contraindications
Cardiopulmonary arrest of the patient
Pneumothorax, unless reduced by chest tube with Heimlich valve in place
Decompression sickness
Arterial gas embolism
Bowel obstruction from any source (commonly postoperative)
Unreduced incarcerated hernia
Volvulus
Intussusception
Laparotomy or thoracotomy within previous 7 days
Presence of intracranial air
Eye surgery within previous 7–14 days
Gas gangrene
Hemorrhagic cerebrovascular accident within previous 7 days
Severe uncorrected anemia (hemoglobin <7.0 g/ml)
Acute blood loss with hematocrit below 30%
Uncontrolled dysrhythmia
Irreversible myocardial infarction
Congestive heart failure with acute pulmonary edema
Acute phase of chronic obstructive pulmonary disease
Acute asthma exacerbation
Acute psychosis
Delirium
Spinal injury unless immobilized
Pregnancy with imminent delivery

Ideal care entails low-altitude evacuation to the nearest recompression chamber.[47] Unfortunately, for security reasons, some nations prohibit civilian flights from cruising below 15,000 feet. Flying a transportable recompression chamber to the patient may be an alternative to delayed treatment.[48]

INFECTIOUS DISEASES

Though travel is often undertaken as an antidote to personal isolation, it is also a notorious vector of contagion. Nations are understandably loath to grant entry to travelers with contagious infections, and certain infectious diseases mandate governmental approval before border crossings are permitted.[49] Under an executive order, the Division of Global Migration and Quarantine of the Centers for Disease Control and Prevention is authorized to quarantine passengers who are suspected of having any one of nine infectious diseases (Table 5).[50]

The World Health Organization provides further information on the transportation of potentially infectious materials and methods of alerting public health officials in suspected cases of highly contagious infectious diseases.[51] For potentially lethal communicable diseases for which no effective treatment is known, an aircraft transit isolator can be used to evacuate a patient to a maximum biologic containment facility. The Aeromedical Isolation Team of the U.S. Army Medical Research Institute of Infectious Diseases deploys teams that use the world's only aeromedical maximum biologic containment suites.[52] Requests for such services are routed through local and state health departments (see the Supplementary Appendix, which is available with the full text of this article at www.nejm.org).

PREPARATION OF PATIENTS

In locations where the stabilization of the patient's condition is not an option and the physical safety of staff is an added concern, the preflight focus is on securing the patient's airway, stopping hemorrhage, and reducing open fractures. All other evacuations should be approached deliberately. Though patients or their families may press for immediate departures, intercontinental flights do not hold the promise of a quick handoff to definitive care. The space-conserving design of airframes thwarts the provision of care equivalent to that in an intensive care unit, so all lifesaving interventions and monitoring procedures (intubation, wound decontamination, and placement of intravenous lines and Foley catheters) that are likely to be needed during the evacuation should be performed before flight, preferably in the departure hospital.[53]

Meticulous "packaging" of patients before flight — including ensuring and securing a patent airway; preventing lines and cords from snagging on transport structures; securing equipment to walls, seats, or stretchers; and spinal immobilization in neck trauma cases — will decrease the risk of injuries associated with handling and turbulence.

Tarmac and aircraft noise smother auditory cues, so capnographs or other devices for the detection of carbon dioxide are invaluable for confirming proper placement of endotracheal tubes in case of displacement during loading or in-flight jostling.[54] Addressing the comfort of patients and alleviating anxiety are important components of care. Patients who start their journeys in tropical climates need to be protected from relative temperature changes within aircraft and when deplaning. Having a family member accompany the patient on the flight improves communication and cooperation.[55]

Aboard commercial flights, overcoming the intricacies of loading nonambulatory patients is time-consuming. Aisles are too narrow for standard wheeled stretchers, so patients must be carried on scoop stretchers or moved on an improvised device. On crowded flights, maintaining the privacy of patients is difficult, and the obvious presence of a working physician aboard a transoceanic flight often elicits requests for care from passengers.

Evacuation physicians will find their skills pushed to include care that would have been provided by nursing and ancillary staff in their home institutions. Immobilized patients require nearly constant attention with positioning, food and drink, toileting, and remoisturizing lips and eyes to counter the discomforts of the ultra-low humidity of aircraft cabins. Airframe vibrations interfere with monitoring devices, and ambient noise decreases the usefulness of stethoscopes and frustrates communication between patients and team members.[55,56]

Anticipating and attending to additional stressors on patients and evacuation teams can reduce the tumult involved in an evacuation. Problems arise when physicians cannot adapt their usual practices to a cramped, crowded, and noisy environment. Such problems are compounded by circadian asynchrony and the loss of situational awareness that results from the prolonged performance of multiple duties that require sustained attention.[57]

Major adverse events occur in about 12% of evacuations.[58] Failed evacuations result from incomplete or rushed assessments of patients, in-transit immobilizations, and fatigue of physicians, especially when those who have spent hours stabilizing a patient embark on a prolonged transport.[59,60] Evacuations are also imperiled when physicians accede to pressure for the early evacuation of unprepared patients.

Table 4. Sample Preflight Checklist.

Confirm there are no contraindications to evacuation
Complete trauma survey
Perform chest radiography to rule out pneumothorax
Perform radiography or computed tomography of facial or skull trauma
Obtain informed consent from the patient or a representative
Check that all pertinent medical equipment is present and functioning
Calculate electrical power and oxygen requirements, including reserves
Secure all lines, tubes, and equipment
Bivalve fresh casts
Remove or deflate air splints
Deflate air-filled balloons (i.e., Foley catheter) or fill with noncompressible fluid (water)
Collect passports and visas for the patient, escort, and evacuation team
Orient the patient (or escort) to emergency egress procedures
Reserve ground ambulance for departure and destination airports
Ensure that lift crews are available at both airports
Ensure that a hospital bed and physician are available at the receiving hospital
Pack all medical records, radiographs, and care documents
Review altitude restrictions (if any) with flight crew
Discuss contingency plans, including diversion options, with flight crew

FLIGHT SAFETY

Statistics from the Flight Safety Foundation reveal an average accident rate of fewer than two per year for international fixed-wing aeromedical flights during the past decade.[61] U.S. studies of EMS airplane accidents highlight the dangers of pilot distraction, nighttime operation, and adverse runway surfaces.[62] Human errors are responsible for three quarters of accidents.[63] Behind the statistics lurks the "rescuer ethic" that drives risk taking and pressure on medical staff to forgo standard flight protocols to save time.[63] The isolation of flight operations from medical decisions may improve safety.[62]

LOGISTICS

QUALITY MEASURES

International aeromedicine is not as developed or as studied as its domestic counterparts in developed nations.[64-69] Self-regulation, uneven training,

Table 5. Nine Diseases for Which Patients May Be Quarantined by Executive Order.*

Influenza viruses that cause pandemics or have pandemic potential
Severe acute respiratory syndrome (SARS)
Cholera
Diphtheria
Infectious tuberculosis
Plague
Smallpox
Yellow fever
Viral hemorrhagic fevers

* Adapted from guidelines of the Division of Global Migration of the Centers for Disease Control and Prevention.[50]

and limited feedback between distant facilities hinder quality-improvement efforts. Provisions of the Emergency Medical Treatment and Active Labor Act are not well known, and direct communication between physicians is often insufficient and sometimes impossible.

Logistic considerations amplify the complexity of international aeromedical evacuation. Such considerations range from the obvious (the need to transfer records) to the mundane (how to pay airport departure taxes). Support personnel can smooth over logistic details and minimize distractions in care. Such personnel should maintain connections with embassies and consulates, so that visas can be rapidly obtained, and with ground transport services, so that fast or slow police escorts from airports to hospitals can be arranged.

COSTS

No private company or commercial airline will perform an evacuation without securing a payment commitment in the form of a guarantee of payment from an insurance or medical assistance company or a preflight transfer of funds from the private account of a patient or a family member. All forms of aeromedical transportation are expensive, but air ambulance service is especially so, with some transoceanic retrievals topping $100,000. Patients and their families are sometimes unhappily surprised to learn that many domestic medical insurance policies (including Medicare and Medicaid) will not cover international aeromedical evacuation or repatriation. During pretravel consultation, physicians can advise patients about acquiring supplemental travel insurance for evacuation, repatriation, or return to country of origin and about the exclusions and limitations of individual policies.

Financial considerations alter the transfer process when economic incentives become entangled with patient advocacy. Physicians who are not involved in the direct care of patients often arbitrate transfer decisions without an appeals process. Assistance companies sometimes contract with travel brokers who solicit bids for evacuations from competing international clinics or retrieval firms. An evacuation represents a substantial financial gain to the company that completes the transfer, whereas providing care in place avoids both transfer costs and the expense of treatment at tertiary care hospitals. Depending on the patient's citizenship, early transport from private pay hospitals to nations with socialized health systems can neutralize the transport-related costs of insurers. By being aware of the varying influences, physicians can aim to maintain a high quality of care and avoid unnecessarily endangering their transport team.

THE FUTURE

International aeromedical evacuation has successfully delivered thousands of distressed travelers to advanced medical care. The field will thrive until the global diffusion of modern equipment, effective treatment, and broadly trained personnel can begin to catch up with the development in multinational industries and tourism. There are encouraging signs that this progress is already occurring. Medical students enthusiastically pursue international health rotations, ministries of health in developing nations and major American and European universities are collaboratively building some of the world's most advanced hospitals in nations that once struggled to provide care, and international medical clinics are succeeding in attracting travelers and native citizens alike. These welcome trends may help convert the ephemeral "air bridges" of aeromedicine to effective permanent medical care in all nations.

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