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Management of In-flight Medical Emergencies

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MORE than two billion passengers board commercial airplanes every year.§ Airline travel is inherently safe and reasonably comfortable, but factors including psychological stress, jet lag, and preexisting disease cause a small number of passengers to become ill while flying. The average age of airline passengers is increasing with that of the general population, and older passengers may have one or more underlying illnesses that impair their ability to adapt to a potentially stressful environment. New, larger airplanes such as the Airbus A380 (Airbus S.A.S., Toulouse, France) may carry twice the number of passengers as current aircraft (more than 800 passengers), which further increases the probability that a medical emergency will occur on any given flight. Physicians who care for a patient who has a serious illness and who wishes to travel may refer to a comprehensive set of medical guidelines for air travel, including a list of contraindications to flight prepared by the Aerospace Medical Association.[1] The regulations governing aviation are complex, and the laws of the aircraft's country of registration primarily regulate training and the provision of emergency medical care aboard airplanes. This article focuses on US Federal Aviation Administration (FAA) regulations that apply to medical emergencies.

Epidemiology

The precise incidence of in-flight medical emergencies is unknown because minor events are probably not reported and there is no central data repository for the majority of events that require medical care. The US National Transportation Safety Board requires that only events resulting in hospitalization for more than 48 h, fracture of any bone (except finger, nose, or toe fractures), or injury to an internal organ be reported as an accident. An FAA study found that 1,132 medical emergencies occurred on flights in the United States during 1996 and 1997, which correlates to an incidence of 13 reported events per day.‖ Two additional studies have estimated the incidence on US flights to be 1 passenger per 39,600.[2] Almost half (47%) of the passengers who became ill were sent to an emergency department, and 10% were admitted to the hospital.[3] In contrast, a British study estimated that one event occurs per 14,000 passengers, corresponding to more than 350 events per day.# The British report does not provide statistics on treatment or passenger disposition.

Several recent studies suggest that the frequency of in-flight medical events on board international flights is increasing.[4] Several causes for this increase have been postulated, including aging passenger population and routine travel on flights of longer duration. Further, the US Department of Transportation requires airlines to carry passengers with disabilities. There is, however, an exemption that allows carriers to refuse transportation if a disabled passenger would endanger the health or safety of other passengers. Moreover, proposed changes to US Department of Transportation regulations would require air carriers to transport passengers who use supplemental oxygen, continuous positive airway pressure, and artificial airways. Under the new regulations, these passengers could travel without medical assistance.

Members of the flight crew may also become incapacitated during flight. Airline pilots are required to undergo a physical examination every 6 months that includes a screening test for diabetes mellitus, an electrocardiogram at age 35 yr, and yearly electrocardiograms after age 40 yr. Despite close medical observation, however, members of the flight crew have required emergency medical care during flight. Air France reported that 10 pilots (total 1,800 pilots) were incapacitated between 1968 and 1988. Causes included cardiac dysrhythmias, seizures, and hypoglycemia. In one instance, an entire cockpit crew was incapacitated as a result of carbon dioxide from improperly packaged dry ice.[5]

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§ IATA Annual Report. Available at: http://www.iata.org/iata/Sites/agm/file/2006/file/annual_report_06.pdf. Accessed May 30, 2007.

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Most in-flight medical events are relatively minor and can be treated without the assistance of a trained volunteer. The most common in-flight emergencies are fainting, near fainting, hyperventilation, and vasovagal episodes. In one study, neurologic, cardiac, and respiratory problems are responsible for the most serious events during flight and accounted for the majority of emergency landings.[2,4] One major airline separately published its medical events; in the year studied, syncope accounted for 15% of complaints, followed by trauma (12%), gastrointestinal disorders (12%), and respiratory events (11%).[6] A separate study found that psychiatric illness accounted for approximately 3.5% of calls to a ground-based consulting service, with the majority of cases diagnosed as acute anxiety.[7] Passengers can sustain injuries from items falling from overhead luggage bins or during turbulent flight.

Children rarely become ill while traveling. A total of 222 in-flight consultations for pediatric emergencies were recorded on a major US airline between 1995 and 2001. The most common pediatric emergency was infectious disease (27%), followed by neurologic (15%) and respiratory illnesses (13%). International flights had the highest incidence of pediatric medical emergencies. The emergency medical kit was used for 60 events, and 19 events required diversion to an alternate airport.[8]

Cabin Environment

Commercial airplanes operate at altitudes between 24,000 feet (7,315 m) and 40,000 feet (12,192 m), which requires that the passenger cabin be pressurized and heated. The barometric pressure (Pb) inside the passenger cabin of most commercial airplanes is equal to that of an altitude of 8,000 feet (2,400 m) above sea level. The barometric pressure in most commercial jets begins to decrease when the airplane climbs through an altitude of 2,400 m and increases when the airplane begins its descent. Pressure changes occur slowly to minimize discomfort. Although most passengers tolerate this environment without adverse effects, decreased atmospheric pressure, extremely dry air (less than 10% relative humidity), and mild hypoxia (arterial oxygen tension [Pa_{O_2}] approximately 55 mmHg) that occurs during flight may exacerbate certain illnesses.

Hypoxia

Dalton's law states that the partial pressure of a gas is the pressure that it would exert if it alone occupied the space containing a gas mixture. The composition of air is constant, but Pb decreases exponentially with altitude, reducing the partial pressure of oxygen (P_{O_2}). According to the alveolar gas equation, at sea level (Pb 760 mmHg), if arterial carbon dioxide tension (Pa_{CO_2}) is 40 mmHg, Pa_{O_2} is 100 mmHg. At 2,400 m (Pb 565 mmHg), P_{O_2} is 118 mmHg, Pa_{O_2} is 55 mmHg, and arterial oxygen saturation (Sa_{O_2}) is 89%, which is well tolerated by most healthy travelers. When Pa_{O_2} decreases below this level, however, the affinity of hemoglobin for oxygen decreases rapidly, and a relatively small decrease in Pa_{O_2} produces a large decrease in oxygen saturation (fig. 1).

The symptoms of hypoxia are cumulative and time related. Increased minute ventilation and increased cardiac output maintain oxygen delivery at a safe level despite decreasing Pa_{O_2}. Above 3,048 m, these normal compensatory mechanisms are insufficient to maintain oxygen delivery, and symptomatic hypoxia may occur. Hypoxia due to impaired gas exchange is exacerbated by

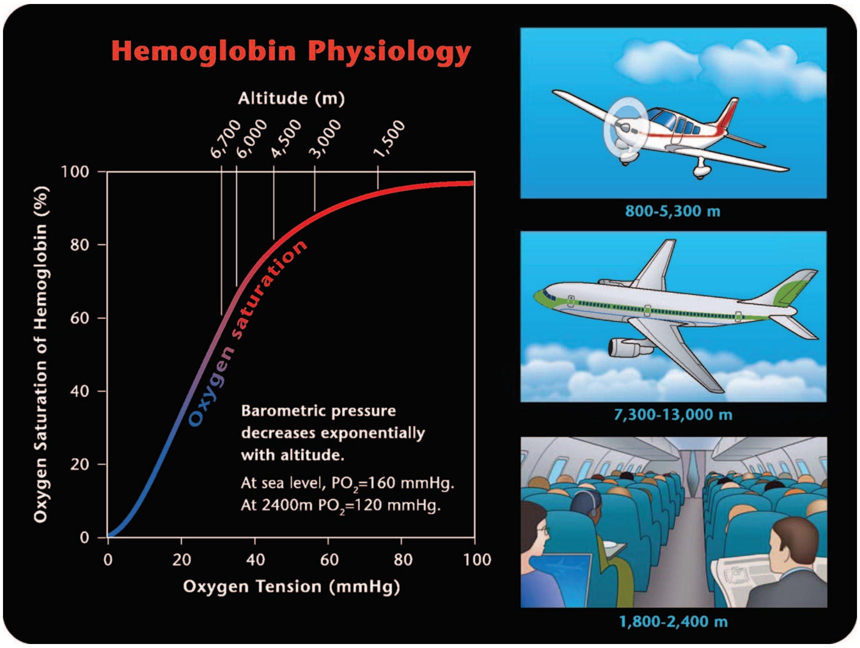

Fig. 1. The hemoglobin–oxygen dissociation curve. Altitude correlating with a given partial pressure of oxygen (P_{O_2}) is at the top of the graph.

decreased oxygen carrying capacity. Chronic smokers, for example, may have mean carboxyhemoglobin levels of 5%, which further increases after smoking, and thus significantly decreases blood oxygen content.[9] Decreased blood flow (*e.g.*, congestive heart failure) may further impair oxygen delivery. As a result, a passenger with obstructive pulmonary disease who has a Pa_{O_2} of 60 mmHg at sea level and 10% carboxyhemoglobin after smoking may be unable to tolerate decreased barometric pressure during flight.

Gas Expansion

At a constant temperature, the volume of gas in an enclosed space varies inversely with pressure (Boyle's law). As a result, the volume of gas in spaces such as the inner ear or a loop of bowel can increase by up to 30% during flight. Therefore, many passengers experience minor otolaryngologic symptoms such as transient decrease in hearing acuity or minor ear and sinus pain.[1] Because gases contained within closed spaces expand during flight, surgical wound dehiscence[10] and spontaneous rupture of bronchogenic cysts and pulmonary bullae have been reported (fig. 2).[11] Medical devices are also affected. Pneumatic splints, feeding tubes, and endotracheal or tracheostomy tube cuffs will expand as cabin pressure decreases.

Decompression Sickness

The amount of gas dissolved in a given volume of liquid is directly proportional to the partial pressure of the gas (Henry's law). When barometric pressure is abruptly decreased, the nitrogen leaves solution and forms gas emboli. Passengers who have been scuba diving within 24 h of flight are at risk of developing decompression sickness. Decompression sickness is caused by nitrogen that accumulates in the body during exposure to high barometric pressure (*i.e.*, during scuba dives). A person with mild decompression sickness may report itching or tingling ("the creeps"). Joint or muscle pain ("the bends") is the most common symptom of decompression sickness; pulmonary gas emboli ("the chokes") or central nervous system involvement may also occur. All are potentially life threatening. The risk of developing decompression sickness increases with age and obesity, geometrically with shorter preflight surface intervals, and dives to greater depths on the last day.[12] As a result, the FAA recommends a 24-h surface interval between scuba diving and flying. Data from a recent study suggest that elderly airline passengers may be at risk for developing gas emboli when exposed to normal in-flight cabin pressure.[13]

Fig. 2. A large right inferior lobe intrapulmonary bulla that expanded during flight in a transport-category jet, causing a gas embolism. From Closson *et al.*[11]; reproduced with permission.

Cabin Air Quality

Cold, dry outside air is heated and compressed by the engine before it is circulated through the cabin. As a result, the relative humidity of air entering the cabin varies from 0 to 10%. This very dry air can exacerbate reactive airway diseases such as asthma and also accelerates the rate of dehydration. The Boeing 787 Dreamliner (Boeing Company, Chicago, IL) uses a novel design to compress and heat cabin air, enabling it to maintain a relative humidity of 30%. Its design also significantly decreases the level of volatile organic compounds entering the cabin. The design of the airplane also allows it to withstand a greater pressure differential so that the minimum pressure in the cabin is equivalent to that at 6,000 feet (1,829 m).

Fresh air entering the cabin is first passed through a catalytic converter to remove ozone and then through a charcoal filter that removes volatile organic compounds such as fuel vapors. A high efficiency particulate air filter then removes particles as small as 0.3 μm.[1,10] Despite this processing, however, compounds such as pesticides, and contaminants entering the airplane can degrade air quality. In some airplanes, cabin air is recirculated, in which case it is mixed with 50% fresh air. In contrast, 80% of the air is recirculated in most commercial buildings.[14]

The air inside the cabin is relatively free of contaminants, but upper respiratory tract infections are common after commercial flight. The most likely reason is that a large number of people are placed in close proximity within a confined environment. Recirculated cabin air does not seem to increase the risk of contracting an upper respiratory tract infection.[15] The most common pathogens in airline passengers who subsequently experienced a respiratory infection included influenza and parainfluenza viruses.

Deep Vein Thrombosis

The association between deep vein thrombosis (DVT) and air travel remains controversial. Asymptomatic DVT was found to occur in 10% of individuals who did not wear venous compression stockings on flights lasting at least 8 h; no thromboses were found in those who wore stockings.[16] Another study of passengers traveling through Charles de Gaulle International Airport (Paris, France) between 1993 and 2000 reported 56 incidents of pulmonary thromboembolism occurred in 135 million passengers.[17] The occurrence rate in this study, however, may be less than that of the general population.[18] Last, a large, well-designed meta-analysis found that long-distance airline travel does not increase the risk of DVT or pulmonary thromboembolism.[19]

Deep vein thromboses that occur during flight may be caused by factors including venous stasis and increased blood viscosity due to dehydration. Recent studies suggest that the incidence of DVT during commercial air travel is low. It seems reasonable, however, to recommend that passengers on long distance flights walk periodically, drink water frequently to avoid dehydration, and consider the use of compression stockings if they are otherwise susceptible to DVT. The diagnosis of pulmonary thromboembolism should be considered in a passenger with risk factors who suddenly develops pleuritic chest pain associated with shortness of breath.

Medical Assistance

The FAA mandates that flight crews receive training in the management of in-flight medical emergencies. This training includes coordination among crew members, the location, function, and operation of emergency medical equipment, and the contents of the emergency medical kit. Flight attendants are also required to undergo training in the use of automated external defibrillators (AEDs) and cardiopulmonary resuscitation every 2 yr. Although flight attendants are required to demonstrate understanding of the procedures involved, their skills are not required to be equivalent to those of a physician or other medical personnel. The FAA has even gone a step further, and specifically states that crew members are not required to provide emergency medical care.

Anesthesiologists receive training in physiology, critical care, and crew resource management and are uniquely qualified to provide assistance. Almost one third of anesthesiologists responding to a survey had offered their assistance during an in-flight emergency, with almost 10% participating in more than one event.[20] A healthcare professional assisted in 69% of all in-flight medical events. Physicians assisted in 40% of events, nurses participated in 25% of emergencies, and allied health professionals such as emergency medical technicians made up the rest. The Aviation Medical Assistance Act of 1998 protects physicians who provide medical assistance while on airplanes registered in the United States. The law protects physicians who offer their services voluntarily, receive no monetary compensation, and render care in good faith. The quality of care must be similar to that which would be provided by other physicians with similar training.** To our knowledge, no physician has been successfully sued in the United States for rendering medical care on an airplane under these circumstances. Although physicians in the United States, Canada, or the United Kingdom are not required to respond to a call for help, the European Union and Australia obligate them to care for a passenger who becomes ill. Moreover, the Tokyo Convention of 1963 allows passengers to take any action necessary to prevent a disruptive passenger from endangering the safety of others.[21]

The pilot in command of the airplane is the ultimate authority for the safety of flight, including the sick passenger. The flight crew is primarily responsible for responding to a passenger who becomes acutely ill, while medically qualified volunteers may provide assistance when requested. Each airline implements its own policies for management of in-flight medical emergencies, with guidance from the Federal Aviation Regulations. Any member of the flight crew may ask a volunteer to administer treatment, discuss the case with ground-based medical personnel, or return to his or her seat.

Emergency Medical Equipment

Commercial airplanes with more than 30 passenger seats are required to carry one or more emergency medical kits. These kits are required to contain specific equipment and medications (table 1). The kits on many airlines exceed the minimum FAA standards. Several airlines have augmented their onboard medical kits to include cardiac medications, sedatives, diuretics, and advanced airway management equipment. In addition to emergency medical kits, US-registered aircraft are required to carry between one and four basic first aid kits (table 2), depending on the number of passengers for which the airplane is configured. European airlines carry the equipment mandated in the US medical kit and also include other drugs such as furosemide, oxytocin, and steroids.

Limited supplies of supplemental oxygen are available if needed. Airlines are required to carry at least enough first aid oxygen to supply 2% of the passengers for the entire flight. The cylinders are equipped with regulators that are designed to provide a flow rate of either 2 or 4 l/min. Setting the flow rate to 2 l/min at a pressure altitude of 2,400 m provides a fraction of inspired oxygen of 28%, which provides a Po_2 equivalent to sea level. It has been recommended that passengers on commercial airline flights who intend to use pulse oximetry should undergo a preflight medical evaluation, carry oxygen with them on the airplane, and have a written plan for monitoring and management of hypoxemia.[22]

** 49 USC 44701. Aviation Medical Assistance Act of 1998.

Table 1. Emergency Medical Kit

Type of Equipment	Contents and Quantity
Diagnostic	1 Sphygmomanometer 1 Stethoscope
Airway management	Oropharyngeal airways: 1 pediatric, 1 small adult, 1 large adult 1 Self-inflating manual resuscitation device Cardiopulmonary resuscitation masks: 1 pediatric, 1 small adult, 1 large adult
Intravenous administration set	1 tubing set with 2 Y connectors 2 Alcohol sponges 1 Roll of 1-inch adhesive tape 1 Pair of tape scissors 1 Tourniquet 1 500 cc bag saline solution
Medication administration	Needles: 2-18 gauge, 2-20 gauge, 2-22 gauge, or other sizes necessary to administer medications Syringes: 1-5 cc, 2-10 cc, or sizes necessary to administer medications
Analgesics	Nonnarcotic analgesic tablets, 325 mg: 4 Aspirin tablets, 325 mg: 4
Antihistamines and bronchospasm	Antihistamine tablets, 25 mg: 4 Antihistamine injectable, 50 mg (single dose): 2 ampoules Metered dose bronchodilator inhaler: 1
Resuscitation	Atropine, 0.5 mg, 5 cc (single dose): 2 Dextrose, 50%/50 cc injectable, (single dose): 1 Epinephrine 1:1000, 1 cc, injectable (single dose): 2 Epinephrine 1:10,000, 2 cc, injectable (single dose): 2 Lidocaine, 5 cc, 20 mg/ml, injectable (single dose): 2
Heart disease	Nitroglycerin tablets, 0.4 mg: 10
Protective equipment	Nonpermeable gloves: 1 pair
Instructions on the use of drugs in the kit	

A list of emergency medical equipment required on board U.S. registered commercial aircraft. Adapted from Federal Aviation Regulation 14 CFR 121.803, Appendix A (Public Domain).

Before the placement of AEDs on airplanes, as many as 1,000 passengers per year were estimated to die as a result of a ventricular dysrhythmia.[23] Since April 2004, commercial flights with at least one flight attendant are required to carry an AED, and these devices have been shown to improve long-term survival rates by 26–40% at a cost less than US $50,000 per quality-adjusted life year.[24] AEDs are designed to administer a shock only if ventricular fibrillation or ventricular tachycardia is detected. Some airlines carry defibrillators that include an electrocardiogram display; these devices can also be used as a cardiac monitor to assist in the diagnosis. Cabin crew members receive training in the operation of AEDs. Many airlines therefore allow only flight attendants familiar with the operation of the AED, and not a physician volunteer, to attach and operate the device.

Policies regarding requests for medical assistance, access to the emergency kit, and treatment of passengers vary among individual airlines. Most airlines will release the emergency kit only to physicians whose identity can be verified. Nonphysician healthcare providers or a senior flight attendant may have access to the emergency kit when under the supervision of a physician in flight or in communication with a ground consultant. Flight attendants may ask for medications over the paging system, but caution should be used when accepting medication in open or unlabeled containers from unknown passengers.

Ground-based Medical Services

Airlines no longer rely only on the chance that a qualified physician will volunteer to assist a passenger

Table 2. First Aid Kit

Contents	Quantity
Adhesive bandage compresses, 1-inch	16
Antiseptic swabs	20
Ammonia inhalants	10
Bandage compresses, 4-inch	8
Triangular bandage compresses, 40-inch	5
Arm splint, noninflatable	1
Leg splint, noninflatable	1
Roller bandage, 4-inch	4
Adhesive tape, 1-inch standard roll	2
Bandage scissors	1

A list of required equipment for first aid kits carried on board commercial aircraft. Adapted from Federal Aviation Regulation 14 CFR 121.803, Appendix A (Public Domain).

who is ill. Most major airlines provide either internal or contracted ground-based medical consulting services with physicians trained in emergency and aerospace medicine. In fact, it is the policy of at least one major airline to contact their ground-based support service first, and only request assistance from a medically trained volunteer if instructed to do so by the consultant. One such company, MedAire® (Phoenix, AZ), provides medical assistance to flight crews of commercial and private jets and ships at sea through a regional medical center in Phoenix, Arizona. These consultants specialize in in-flight emergencies and advise aircrews and physician volunteers as to differential diagnoses and treatment options. MedAire® also provides lists of intermediate airports with access to emergency medical services suitable to a specific emergency. Should a dispute arise between the onboard physician and the ground-based consultant regarding diversion, the captain will usually comply with the recommendation of the ground-based consultant.

Unscheduled Landings (Flight Diversion)

If a passenger is extremely ill, it may be necessary to land at an intermediate airport. Unplanned landings (diversions) due to an in-flight medical emergency result in significant delays and expenses for the airline, the sick passenger, and everyone else on the flight. Because the timing of a medical event cannot be predetermined, diversions may result in landings at airports with which the flight crew is not familiar. Although airlines do not publish the cost of diversion for a medical emergency, it has been estimated to be between $15,000 and $893,000.[25] Airlines will therefore solicit the agreement of their ground-based consultant before diverting the flight, and the ultimate decision to divert rests with the pilot in command.

General Management Strategies

Given the focus of this review, it is difficult to recommend specific management strategies, but it is possible to make general recommendations. Before volunteering to provide medical assistance, physicians should carefully assess their ability to do so. They should not volunteer if they have recently ingested alcoholic beverages or central nervous system depressants. Medical volunteers should be prepared to show a form of identification (such as a medical license or hospital identification card) that verifies their training. The volunteering physician must obey all instructions from the flight crew, who will ensure that caring for the sick or injured passenger does not endanger the safety of others. Medical volunteers should stay well within their level of competence. Good Samaritan laws offer protection only to volunteers who provide treatment that another reasonable physician would have provided.

If a passenger becomes ill during flight, the immediate priorities are to quickly locate oxygen and medical equipment, ask for and use any help available, delegate responsibility when appropriate, and suggest diversion if it will be of benefit to the patient. The goal of in-flight medical assistance is to stabilize the patient and advise the flight crew as to a diagnosis and treatment. In addition, when appropriate, the volunteer should seek consultation from ground-based medical support personnel and suggest diversion of the aircraft to an alternate airport. The limited amount of space available makes medical treatment a logistical challenge. If possible, treating the passenger in his or her seat is the safest option. If this is infeasible, the patient may be relocated to an aisle or galley, or to the first or business class section at the discretion of the flight crew. Treating the patient in an aisle should be avoided if possible, because it will impair the ability of the flight crew to perform their required duties. If the passenger and physician do not speak a common language, flight crew, family members, or other passengers may be asked to assist with translation. Diversion should be recommended if the passenger reports unremitting chest pain, shortness of breath, or severe abdominal pain.

The patient's initial complaint, medical history, and physical findings, along with treatment administered during flight, should be documented. Many airlines have preprinted forms for this purpose. Documentation is especially important if the passenger is being transported to a hospital, because the treating physician will not be able to accompany him or her and because symptoms may disappear when cabin pressure is increased.

Providing assistance to an airline passenger who becomes ill during flight is challenging and requires an understanding of physiologic adaptations to flight. Successful outcome requires flexibility and crew resource management skills. Anesthesiologists manage complicated, unpredictable situations as a routine part of their workday and may be uniquely qualified to ring the call button when a physician is asked to identify him or herself.

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