Is There a Doctor Onboard? Medical Emergencies at 40,000 Feet

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• Wilderness medicine • In-flight medical emergencies • Flight attendants • FAA

INTRODUCTION

It is estimated 2.75 billion people travel aboard commercial airlines every year and 44,000 in-flight medical emergencies occur worldwide each year.[1] Wilderness medicine requires a commonsense and improvisational approach to medical issues. A sudden call for assistance in the austere and unfamiliar surroundings of an airliner cabin may present the responding medical professional with a "wilderness medicine" experience. From resource management to equipment, this article sheds light on the unique conditions, challenges, and constraints of the flight environment.

THE FLIGHT ENVIRONMENT

Modern commercial aircraft fly at the interface between the troposphere and stratosphere, roughly equivalent to a cruising altitude of 32,000 to 45,000 feet. Above the troposphere, planes fly more smoothly and experience less turbulence and inclement weather. The height of the troposphere varies with altitude and season. Passengers are protected from high-altitude atmospheric conditions by a pressurized cabin environment that potentially creates its own medical ramifications.

CABIN ALTITUDE

The ambient atmospheric pressure at cruising altitude (30,000–40,000 feet) is about 200 to 300 hPa (roughly 0.2–0.3 atm). To allow passengers to survive and operate in this environment, the cabin must be pressurized. Despite pressurization, the internal cabin altitude is generally not maintained at sea level pressure because the aircraft structure required to maintain a sea level pressure would make the plane unacceptably heavy and expensive to build and operate. Thus, a compromise is made that is the most efficient for weight/strength/expense, while preventing passengers from

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becoming hypoxic. The aircraft cabin is typically pressurized between 6000 and 8000 feet above sea level. Newer aircraft, such as the Airbus A380 and Boeing 787 Dreamliner, can pressurize the cabin to lower altitudes, equal to about 6000 feet, even in the upper flight levels. In the United States, Federal Aviation Administration (FAA) requirements allow a maximum cabin altitude of 8000 feet.

Many people with heart and lung disease travel by commercial aircraft, and are unaware of the risk that is incurred. The fractional oxygen content of the air in the cabin is the same as that at sea level, approximately 21%. What changes with increasing cabin altitude is the atmospheric pressure. At a typical cruising altitude, the atmospheric pressure in the cabin is decreased by about 25% to 30% and results in a similar decrease in the partial pressure of inspired oxygen. The lower partial pressure of oxygen in the aircraft cabin results in slight hypoxemia, with a corresponding decrease in oxygen saturation and a mild compensatory hyperventilation and tachycardia. Medical personnel responding to onboard medical events should not be surprised by decreases in arterial oxygen saturation in the range of 3% to 5%, even in healthy individuals.

PRESSURE AND DYSBARISM

Boyle's law states that in a perfect gas where mass and temperature are kept constant, the volume of the gas varies inversely with the absolute pressure.

$$(P \times V = P' \times V')$$

Reduction in aircraft cabin pressure can lead to volume expansion of closed gas-containing compartments in the human body.

Middle Ear

Expanding volumes of air in the paranasal and frontal sinuses may produce symptoms, but the most common manifestation of dysbarism associated with the flight environment is barotitis media resulting in ear pain. Barotitis media is commonly related to eustachian tube congestion secondary to upper respiratory infections, middle ear infections, chronic effusions, or allergies. Mild barotrauma may occur as either pressure increase caused by expansion of gases as the aircraft ascends, or by decreased pressure in the middle ear as the aircraft descends. Although mild discomfort is the typical presentation, in rare cases, the changes in pressure can produce rupture of the tympanic membrane.

The most simple and commonly used method to open the eustachian tube is to swallow. Chewing gum or sucking on hard candy may facilitate this process. Infants should be given a bottle or pacifier to suck on to facilitate swallowing, especially during descent.

Older children and adults may benefit from performing a Valsalva maneuver. This is achieved by pinching the nostrils and attempting exhalation through the nose. This maneuver is familiar to most scuba divers, because the same technique is used for equalizing ears during descent. Another useful technique is to have the patient swallow while pinching the nostrils closed. Other pressure equalization techniques[2] include the following:

- Voluntary tubal opening: Attempt to yawn or wiggle the jaw
- Valsalva maneuver: Pinch your nostrils, and gently blow through your nose
- Toynbee maneuver: Pinch your nostrils and swallow (good technique if equalization is needed during ascent)
- Frenzel maneuver: Pinch your nostrils while contracting your throat muscles, and make the sound of the letter "k"

- Lowry technique: Pinch your nostrils, and gently try to blow air out of your nose while swallowing
- Edmonds technique: Push your jaw forward, and use the Valsalva maneuver or the Frenzel maneuver

Dental

Cabin pressure changes may cause toothaches in patients with pre-existing dental disease, such as a dental abscess (barodontalgia).

Abdomen

Occasionally, intraluminal gas expansion caused by decreased cabin pressure may cause abdominal discomfort. The surgical literature contains references regarding complications during flight subsequent to recent abdominal surgery.[3,4] Travelers should be advised to check with their surgeon. The British Civil Aviation Authority publishes the following recommendations.[5]

- Travel should be avoided for 10 days following abdominal surgery.
- Following procedures, such as colonoscopy, where a large amount of gas has been introduced into the colon, it is advisable to avoid travel by air for 24 hours.
- It is advisable to avoid flying for approximately 24 hours after laparoscopic intervention, because of the residual CO_2 gas, which may be in the intra-abdominal cavity.
- Neurosurgical intervention may leave gas trapped within the skull, which may expand at altitude. It is therefore advisable to avoid air travel for approximately 7 days following this type of procedure.
- Ophthalmologic procedures for retinal detachment involve the introduction of gas by intraocular injections, which temporarily increase intraocular pressure. Depending on the gas, it may be necessary to delay travel for approximately 2 weeks if sulfur hexafluoride is used and 6 weeks pursuant to the use of perfluoropropane. For other intraocular procedures and penetrating eye injuries, 1 week should elapse before flying.

Gas Expansion and Medical Devices

Various medical devices that trap fixed quantities of expandable air must be considered when transporting patients aboard aircraft. Expanding trapped gas within these devices has been known to cause barotrauma during rapid ascent in unpressurized and pressurized aircraft. A partial list of these devices includes pneumatic splints (air splints), feeding tubes, urinary catheters, cuffed endotracheal tubes, and cuffed tracheostomy tubes.

If not contraindicated, the effects of gas expansion can be eliminated by installation of water rather than air during flight. These devices require careful monitoring; partial deflation should be considered if overexpansion is suspected. Feeding and infusion tubes should be capped off.

Pneumothorax

Travelers with pre-existing pulmonary disease are at risk for flight-related pneumothorax. A patient with a small, asymptomatic pneumothorax can develop a more significant pneumothorax as air expands within the pleural space during ascent. Risk of pneumothorax during air travel is increased in patients with cystic lung disease, recent pneumothorax, thoracic surgery, and chronic pneumothorax.[6]

FLYING AFTER SCUBA DIVING

Guidelines for Postdive Air Travel

The Divers Alert Network and the Undersea Hyperbaric Medical Society convened a workshop in 2002 to review the available data regarding postdive air travel. The published guidelines (Table 1) do not guarantee that one will avoid decompression sickness. Allowing even longer surface intervals than the recommended minimums further reduces the risk of decompression sickness.

There are additional considerations regarding the Divers Alert Network/Undersea Hyperbaric Medical Society flying after diving guidelines.[7] It is prudent to wait longer than the suggested minimum interval. Recent studies show that flying in a commercial aircraft, even after a 24-hour surface interval, can produce bubbles in a diver's blood; therefore, Divers Alert Network advises that one exercise caution by maintaining more conservative dive profiles during the final day of diving and plan for a 24-hour surface interval before flight. Any postdive ascent to a higher altitude—even using ground transportation—increases decompression stress, so one should follow the same guidelines if heading by car, bus, or foot from a dive site to the mountains.

CABIN AIR

Despite the pervasive antipathy expressed by airline passengers, there is little clinical evidence to suggest that cabin air quality on modern jets is potentially harmful. Many airline passengers have anecdotes about getting sick following a long duration flight. The risk of contracting an infection during a commercial flight arises from the close proximity to potentially germ-laden fellow passengers, and not from the quality of aircraft cabin air. A crowded airplane poses no greater risk than other enclosed spaces.

A portion of the cabin air (no more than 40%–50%) is recirculated and passes through high-efficiency particulate air filters. According to Boeing, between 94% and 99.9% of all airborne microbes are filtered during this process. The other source of cabin air is "bleed air" that is obtained when outside air is compressed by the aircraft's engines. The incoming bleed air is plumbed into air conditioning units for cooling. This mix of recirculated cabin air and outside bleed air makes it possible to efficiently regulate temperature and humidity.

Newer aircraft use high-efficiency particulate filters to remove gaseous contaminants, including some volatile organic compounds that may act as mild respiratory irritants.

Fume Events

In the event of an oil leak, bleed air may be exposed to gasses that could potentially expose passengers to neurotoxins. Such events are rare, but have reportedly

Table 1
Divers Alert Network guidelines for flying after diving

Dive Profile	Minimum Preflight Surface Interval Suggestion
Single no-decompression dive	12 h or more
Multiple dives in a day	18 h or more
Multiple days of diving	18 h or more
Dives requiring decompression stops	Substantially longer than 18 h

From Flying after scuba diving: how long should I wait? Divers Alert Network; 2016; and *Data from* DAN Medical Frequently Asked Questions. Available at: http://www.diversalertnetwork.org/medical/faq/Flying_After_Diving.

triggered neurologic symptoms, such as headaches and dizziness in crewmembers and passengers. Jet engine oils contain synthetic hydrocarbons and other additives, including the organophosphate tricresyl phosphate, which acts as a high-pressure lubricant. Most studies indicate that total tricresyl phosphate concentrations occurring during so-called fume events remain below threshold limits for causing neurologic symptomatology.[8] The concentration of organophosphates that aircraft crewmembers and passengers could be exposed to is insufficient to produce neurotoxicity.[9] A recent guide for health care providers concluded that "there are currently no tests of sufficient sensitivity and specificity to assess exposure/health effects outcomes."[10]

The newest Boeing airliner, the 787 Dreamliner, uses a no-bleed systems architecture that replaces the conventional pneumatic bleed air system with a high-power electrical compressor system that avoids any mixing of engine-based bleed air with internal cabin air.

Infectious Disease and Air Travel

Although modern airliners provide clean cabin air, air travelers are still subjected to long periods in enclosed spaces, which facilitates the spread of infectious disease. Multiple outbreaks of serious infectious diseases have been reported aboard commercial airlines including influenza, food poisoning, measles, tuberculosis, viral enteritis, severe acute respiratory syndrome, and smallpox.

The risk of cross-infection from airborne pathogens in aircraft cabins seems to be related to the duration of the flight (with 8 or more hours producing an increased risk), and proximity of the index passenger (seating within two rows associated with an increased risk).[11,12]

If a contagious disease is suspected, ask the ill passenger to use a facemask. A mask should be available in the medical kit and/or the first aid kit. Use of a facemask by the ill passenger is recommended by the World Health Organization.[13] Attempt to isolate the patient and relocate neighboring passengers. Discuss quarantining the passenger with the flight crew and any reporting requirements.

Low Humidity of Cabin Air

Airliner cabins are dry. Typical humidity levels in most airliners are about 2%. Airplane designers are happy to minimize moisture to help inhibit structural corrosion. Maintaining optimal cabin humidity (40%–70%) is prohibitive because of the increased cost and weight of equipment. The newer Boeing 787 does not use engine bleed air to pressurize the cabin. The 787 cabin contains 6% to 7% humidity, which according to studies done by Boeing improves the passenger experience. Low cabin humidity levels can lead to dehydration, so passengers are encouraged to increase water intake. Dry eyes can be especially problematic for travelers with pre-existing conditions and for soft contact lens wearers. Carrying "artificial tears" or contact rewetting drops is of benefit. Dry inflamed upper respiratory mucosa can produce cough and exacerbate reactive airway disease.

COSMIC-RADIATION EXPOSURE

Cosmic radiation originates from powerful events, such as star collisions, gamma ray bursts, black holes, and supernovae. Particles released by solar flares are another source. The earth's magnetic field and atmosphere shield the planet from 99.9% of cosmic radiation; however, for travelers outside the protection of Earth's magnetic field, space radiation becomes a more potential hazard. Exposure levels also rise when we travel by plane, especially at higher altitudes and latitudes.

In 1991, the International Commission on Radiological Protection declared cosmic radiation an occupational risk for flight crews. Since that time, exposure monitoring and maximum dose guidelines have been developed. Current recommendations are to limit annual crew exposure to 20 mSv/y averaged over 5 years (total of 100 mSv in 5 years).[14,15] Even frequent flyers and aircrews typically remain well below this limit.

Concerns increase when considering the developing fetus during pregnancy.[16] The National Council on Radiation Protection and Measurements recommends a monthly limit of 0.5 mSv, whereas the International Commission on Radiological Protection recommends a radiation limit of 1 mSv during the entire pregnancy. These recommendations would place limits on pregnant crewmembers and frequent air travelers, because flying roughly 15 long-haul round trips would expose a fetus to more than 1 mSv. To avoid risk to the fetus, the FAA recommends pregnant crewmembers take shorter, low-altitude, low-latitude flights.

The Centers for Disease Control and Prevention[17] recommends that if you are pregnant and aware of an ongoing solar particle event, that you reschedule your flight. A National Institute for Occupational Safety and Health (NIOSH) study found that flight attendants exposed to 0.36 mSv or more of cosmic radiation in the first trimester may have a higher risk of miscarriage. Although flying through a solar particle event is rare, a NIOSH and National Aeronautics and Space Administration study found that a pregnant flight attendant who flies through a solar particle event can receive more radiation than is recommended during pregnancy by national and international agencies.

How to Reduce Exposure

Ultimately the amount of cosmic radiation exposure received while flying depends on the amount of time in the air, altitude, latitude, and solar activity. Lowest dose rates at a given altitude are found close to the equator and intensify with increasing latitude. For any location at commercial flight altitudes, a higher altitude incurs a higher dose rate. Reducing aircraft altitude can significantly reduce radiation exposure during a solar radiation event in high-latitude areas.[18] With regard to solar particle events, the Centers for Disease Control and Prevention[17] states

- NIOSH has estimated that pilots fly through about six solar particle events in an average 28-year career.
- Avoiding exposure to solar particle events is difficult because they often happen with little warning. One can find out whether a solar particle event is currently active through these sources:
  - The National Aeronautics and Space Administration Nowcast of Atmospheric Ionizing Radiation System is being developed to report potentially harmful flight radiation levels to flight crews and passengers.
  - National Aeronautics and Space Administration Nowcast of Atmospheric Ionizing Radiation System: current radiation dose rate forecast.
  - A space weather app for the iPhone offers current information on solar activity (developed by Stellar North LLC).
  - The National Oceanic and Atmospheric Administration Space Weather Prediction Center's Aviation Community Dashboard includes a forecast for solar particle events.
  - A useful tool to estimate an individual's exposure to cosmic radiation from a specific flight is available from the FAA on its Web site (http://jag.cami.jccbi.gov/cariprofile.asp).

EMOTIONAL AND PHYSICAL STRESS DURING AIR TRAVEL

Travelers are often subject to conditions that increase anxiety and overall dysphoria during air travel, including the following:

- Time pressures of travel
- Airport congestion
- Rushing to make connecting flights
- Stress and anxiety associated with business travel
- Stress and anxiety associated with family-related events, such as reunions, weddings, and funerals
- Psychosocial disruptions in circadian rhythms (discussed next)
- Emotional effects of lack of sleep and dehydration
- Stress and anxiety associated with missed and canceled flights
- Unexpected layovers

JET LAG

Circadian Rhythm Sleep Disorder (Jet Lag)

Jet lag is a sleep disorder occurring in travelers who transit across three or more time zones. Jet lag occurs when the internal circadian rhythm "clock" adjusts slowly to the destination time. This disruption causes circadian rhythms to become out of synchronization with the destination time zone.

The pineal gland is highly involved with regulating the sleep-wake cycle by secreting melatonin. The synthesis and release of melatonin is stimulated by darkness and suppressed by light.[19]

Symptoms

Symptoms may include poor sleep, including sleep-onset insomnia, fractionated sleep, and early awakening; fatigue; mood changes; headache; irritability; poor concentration; depression; and mild anorexia.

Clinical Considerations

Although there is substantial individual variability in the severity of jet lag symptoms, the direction of travel and the number of time zones crossed are important factors to consider.[19,20] Specifically, westward travel generally causes less disruption than eastward travel.[21]

- Eastward travel is associated with difficulty falling asleep at the destination bedtime and difficulty arising in the morning.
- Westward travel is associated with early evening sleepiness and predawn awakening at the travel destination.
- Travelers flying within the same time zone typically experience the fewest problems, such as nonspecific travel fatigue.
- Crossing more time zones or traveling eastward generally increases the time required for adaptation.
- After eastward flights, jet lag lasts for the number of days roughly equal to two-thirds the number of time zones crossed; after westward flights, the number of days is roughly half the number of time zones.
- The intensity and duration of jet lag are related to the number of time zones crossed, the direction of travel, the ability to sleep while traveling, the availability and intensity of local circadian time cues at the destination, and individual differences in phase tolerance.

Prevention

Travelers can minimize jet lag by doing the following before travel[19]:

- Shift the timing of sleep to 1 to 2 hours later for a few days before traveling westward
- Shift the timing of sleep to 1 to 2 hours earlier for a few days before traveling eastward
- Shift mealtimes to hours that coincide with the previous changes
- Seek exposure to bright light in the evening if traveling westward, in the morning if traveling eastward
- Mobile apps, such as Jet Lag Rooster and Entrain, are available to help travelers calculate and adhere to a light/dark schedule
- Web sites, such as Jet Lag Advisor (http://www.britishairways.com/travel/drsleep/public/en_gb), offer similar services online; travelers answer a few simple questions regarding planned flights and advice is then calculated to minimize jet lag

Pharmacologic Treatment

The use of the nutritional supplement melatonin is controversial for preventing jet lag.[19] Some clinicians advocate the use of 0.5 to 5.0 mg of melatonin during the first few days of travel, and data suggest its efficacy.[22] The production of melatonin is not regulated by the Food and Drug Administration and commercially available products have demonstrated impurities. Additionally, current data also do not support the use of special diets to ameliorate jet lag. If used, timed treatment with melatonin in the early morning of the departure time zone (westward) or the very early evening of the departure time zone (eastward) preflight and postflight may improve initiation and maintenance of the desired phase shift.[23]

Newer melatonin receptor agonists, such as ramelteon, have recently been approved for the treatment of insomnia, but have not been well studied for use in jet lag.

The 2008 American Academy of Sleep Medicine[24] recommendations include the following:

- Promote sleep with hypnotic medication, although the effects of hypnotics on daytime symptoms of jet lag have not been well studied.
- Nonaddictive sedative hypnotics (nonbenzodiazepines), such as zolpidem, have been shown in some studies to promote longer periods of high-quality sleep. If a benzodiazepine is preferred, a short-acting one, such as temazepam, is recommended to minimize oversedation the following day. Because alcohol intake is often high during international travel, the risk of interaction with hypnotics should be emphasized with patients.
- If necessary, promote daytime alertness with a stimulant, such as caffeine in limited quantities. Avoid caffeine after midday.[25]
- Take short naps (20–30 minutes), shower, and spend time in the afternoon sun.

HEALTH ISSUES ASSOCIATED WITH COMMERCIAL AIR TRAVEL

Airlines are not required to report emergencies unless they require actual diversion of the flight. A recent article provides an extensive review of in-flight emergencies.[1] This article reviewed records of in-flight medical emergency calls from five domestic and international airlines to a physician-directed medical communication center from January 1, 2008, through October 31, 2010. During the study period there were approximately 744 million airline passengers who traveled on commercial airline flights. The communications center received 11,920 in-flight medical emergency calls (a rate of 16 medical emergencies per 1 million passengers). The incidence of in-flight medical emergencies was one in-flight medical emergency per 604 flights. The most common medical problems were syncope or presyncope (37.4%), respiratory symptoms (12.1%), and nausea or vomiting (9.5%).

Aircraft diversion occurred in 7.3% of cases, whereas 1.2% of patients resolved sufficiently before landing to negate the need for emergency medical service (EMS) services on landing. Only 37.3% of patients evaluated by EMS personnel after landing were transported to a hospital emergency department.

Medical problems that were associated with the highest rates of hospital admission were stroke-like symptoms (23.5%), obstetric or gynecologic symptoms (23.4%), and cardiac symptoms (21%). Although most of the medications that were used are available in the FAA emergency medical kit (EMK) (discussed later), some medications came from other passengers or the patient themselves. The most commonly used medications were oxygen (49.9%), intravenous (IV) normal saline (5.2%), and aspirin (5%).

Automated External Defibrillators

An automated external defibrillator (AED) was used on 137 patients (1.3%). An AED was applied in 24 cases of cardiac arrest but shock delivered in only five cases. The return of spontaneous circulation occurred in one patient receiving defibrillation. For eight other patients, an AED was used but no shock was indicated.

Death Rate

The death rate among all patients with in-flight medical emergencies was 0.3%. **Table 2** shows medical emergencies according to medical problem and outcome.

Ground-Based Consultation

For medical professionals responding to an in-flight emergency, their unfamiliarity with the flight environment can be anxiety provoking. Many physicians believe that they are inadequately trained or naive to operational aspects of the flight, such as indications for diversion, protocols, and equipment.

Health care providers should know that when they respond to an in-flight emergency, they are essentially never operating alone. There are multiple networks of ground-based consultants working closely with all domestic airlines in the United States and most foreign carriers.

The responsibility of deciding whether the plane needs to be rerouted is ultimately a decision made by the pilot. As a medical professional, your primary obligation is to offer your best medical opinion about the patient's condition and prognosis, including the degree of urgency.

In most cases, the pilot will probably have already contacted their own ground-based consultants before the flight attendant's call for assistance. You will be acting as the eyes and ears for the specialist on the ground that has familiarity with the environment and deals with these problems on a regular basis. The ground-based consultants can offer important information on resources, such as, medical kit contents, diagnostic capabilities, and airline operations.

Although the FAA does not officially require consultation with a ground-based consultant in the case of in-flight emergencies, all domestic airlines collaborate with specific agencies specializing in aeromedical emergency medical care. Most airline flight crews are advised to use these consultants for all in-flight medical emergencies. Additionally, most airlines require a consultation with the ground-based physician

Table 2
In-flight medical emergencies and outcome

		Aircraft Diversion	Transport to a Hospital[a]		
Category	All Emergencies	n/N (%)		Hospital Admission[b]	Death, n
All categories	11,920/11,920 (100)	875/11,920 (7.3)	2804/10,877 (25.8)	901/10,482 (8.6)	36
Syncope or presyncope	4463/11,920 (37.4)	221/4463 (5.0)	938/4252 (22.1)	267/4123 (6.5)	4
Respiratory symptoms	1447/11,920 (12.1)	81/1447 (5.6)	311/1371 (22.7)	141/1336 (10.6)	1
Nausea or vomiting	1137/11,920 (9.5)	56/1137 (4.9)	243/1025 (23.7)	61/994 (6.1)	0
Cardiac symptoms	920/11,920 (7.7)	169/920 (18.4)	370/813 (45.5)	162/770 (21.0)	0
Seizures	689/11,920 (5.8)	83/689 (12.0)	224/626 (35.8)	75/602 (12.5)	0
Abdominal pain	488/11,920 (4.1)	50/488 (10.2)	164/412 (39.8)	41/391 (10.5)	0
Infectious disease	330/11,920 (2.8)	6/330 (1.8)	45/239 (18.8)	8/232 (3.4)	0
Agitation or psychiatric symptoms	287/11,920 (2.4)	16/287 (5.6)	38/249 (15.3)	17/244 (7.0)	0
Allergic reaction	265/11,920 (2.2)	12/265 (4.5)	40/233 (17.2)	8/229 (3.5)	0
Possible stroke	238/11,920 (2.0)	39/238 (16.4)	92/214 (43.0)	46/196 (23.5)	0
Trauma, not otherwise specified	216/11,920 (1.8)	14/216 (6.5)	34/185 (18 4)	5/180 (2.8)	0
Diabetic complication	193/11,920 (1.6)	15/193 (7.8)	45/181 (24.9)	13/172 (7.6)	0
Headache	123/11,920 (1.0)	10/123 (8.1)	23/108 (21.3)	4/107 (3.7)	0
Arm or leg pain or injury	114/11,920 (1.0)	6/114 (5.3)	27/100 (27.0)	4/98 (4.1)	0
Obstetric or gynecologic symptoms	61/11,920 (0.5)	11/61 (18.0)	29/53 (54.7)	11/47 (23.4)	0
Ear pain	49/11,920 (0.4)	1/49 (2.0)	2/43 (4.7)	1/43 (2.3)	0
Cardiac arrest	38/11,920 (0.3)	22/38 (57.9)	14/34 (41.2)	1/6 (16.7)	31
Laceration	33/11,920 (0.3)	1/33 (3.0)	3/26 (11.5)	0/25	0
Other	821/11,920 (6.9)	62/821 (7.6)	162/705 (23.0)	36/679 (5.3)	0
Unknown	8/11,920 (0.1)	0/8	0/8	0/8	0

[a] Postflight follow-up data on transport to a hospital by emergency medical service personnel were available for 10,877 of the 11,920 passengers with in-flight medical emergencies (91.2%).
[b] Postflight follow-up data on hospital admissions were available for 10,482 of the 11,920 passengers with in-flight medical emergencies (87.9%). Admitted patients were defined as those transported to the hospital who were admitted from the emergency department or who left the emergency department against medical advice, excluding patients who died.

From Peterson DC, Martin-Gill C, Guyette FX, et al. Outcomes of medical emergencies on commercial airline flights. N Engl J Med 2013;368(22):2077; with permission.

before the EMK is used. It should be noted that all communications with medical ground consultants are recorded.

Cockpit Coordination

Typically, the pilot in command or captain takes over the cockpit management of the medical emergency. This requires that the copilot or "First Officer" take over the responsibility of flying the aircraft. The pilot not flying would then notify air traffic controllers about the medical emergency. In the United States a pilot essentially always makes the decision to divert in consultation with a ground-based consultant.

Diversion

Diverting to a closer airport creates several logistical problems for the flight crew, including

- Medical capabilities and resources within close proximity to the landing airport
- Weather conditions
- Availability of instrument approaches in nonvisual flight conditions
- Runway size
- Availability of additional flight and cabin crew, if necessary, after landing to continue the flight
- Maintenance facilities and handling capabilities at the landing airport
- Availability of jet fuel
- Major inconvenience to the remaining passengers

When diversion is necessary during the early phase of a flight, the aircraft may still exceed maximum landing weight because of the additional fuel carried. Pilots can either land overweight, fly in circles or other holding patterns to burn off excess fuel, or dump fuel. Many modern aircraft have the capability to vent fuel overboard in the case of a grossly overweight landing situation.

According to Ruskin and colleagues[26] and Grendreau and DeJohn,[27] diversion should be recommended for the following:

- Unremitting chest pain
- Shortness of breath
- Severe abdominal pain
- Stroke
- Persistent unresponsiveness
- Refractory seizures
- Severe agitation

MEDICAL-LEGAL CONSIDERATIONS

In 1998 the US Congress enacted a federal statute to limit the liability of medically qualified individuals responding to medical emergencies aboard commercial airliners registered in the United States. The motivation of the Aviation Medical Assistance Act (AMAA) was to reduce concerns over the legal ramifications of assisting in an in-flight emergency should the outcome generate litigation. The AMAA, in its Section on Limitations on Liability, states[28]:

> *An individual shall not be held liable for damages in any action brought in a Federal or State court arising out of the acts or omissions of the individual in providing or attempting to provide assistance in the case of an in-flight medical emergency*

unless the individual, while rendering such assistance, is guilty of gross negligence or willful misconduct.

Gross negligence or willful misconduct constitute more than simple errors. This term indicates that a physician has departed substantially from minimally accepted medical care or has shown egregious behavior while providing care. An example of such flagrant disregard for the patient's health and safety is an intoxicated physician treating a patient.[29]

The immunities of the AMAA are not dependent on the care being provided without compensation; however, airlines recently have been sympathetic to the notion that compensation muddies the waters in regard to "Good Samaritan" law.

What if a health care provider is administering care on an international airline not registered in the United States? The inherent rule is that the laws of the country in which the carrier is based apply.[30] Other experts have argued that the laws of the country in (or over) which the incident occurs or where the parties are citizens could apply.[27] Some countries, such as Australia and countries in the European Union, impose a legal duty on the physician to respond. The United States, Canada, and the United Kingdom do not stipulate this requirement to act.[31]

The AMAA also extends immunity from liability to air carriers registered in the United States with regard to damages arising from assistance provided during an in-flight medical emergency. The AMAA, in its Section on Liability of Air Carriers, states[28]:

An air carrier shall not be liable for damages in any action brought in a Federal or State court arising out of the performance of the air carrier in obtaining or attempting to obtain the assistance of a passenger in an in-flight medical emergency, or out of the acts or omissions of the passenger rendering the assistance, if the carrier in good faith believes that the passenger is a medically qualified individual and not an employee or agent of the carrier.

Volunteers must be "medically qualified" and receive no monetary compensation to receive protection.[32] Airline employees meet the "in good faith" requirement by asking whether the person who volunteers to help is a health care provider (see the article on medical-legal issues in expedition and wilderness medicine elsewhere in this issue for more legal considerations).[30]

If a patient requires ongoing monitoring and therapy, the volunteer may need to stay by their side for the duration of the flight. Many airlines carry a "standard airline medical incident form." If this is available, use it for appropriate documentation. If there are no forms available, improvise using any means of documentation (**Table 3**).[33] When completed, request a copy, or photograph it with your smart phone for future

Table 3
Sample basic inflight report

Date
Airline
Flight #
History
Past medical history
Examination
Treatment
Disposition

reference. If the patient remains unstable, be prepared to continue offering assistance throughout the remainder of the flight. After landing, it is acceptable to hand over care to ground-based medical personnel for transfer to definitive care.

Emergency Medical Kits

FAA regulations regarding EMKs (**Fig. 1**) are as follows (see **Table 4** for the approved EMK[34] contents):

- The FAA has required EMKs and AEDs on all commercial airplanes with a maximum payload capacity of more than 7500 pounds and with at least one flight attendant since 1986.[34]
- The EMK is designed based on recommendations from the Aerospace Medical Association's Air Transport Medicine Committee.
- The medications that must be carried in all EMKs have an expiration date of approximately 1 year. The FAA advises that the best practice is to replace all of the medications annually.
- In 1994, examination gloves were added to the medical kits.
- In 2004, an updated kit, the enhanced EMK, was added to the requirement. The enhanced EMK added oral antihistamines, nonnarcotic analgesics, a bronchodilator, aspirin, injectable atropine, additional epinephrine, IV lidocaine, IV saline, and a bag valve mask. An AED was also required.
- FAA regulations state that a flight may not depart if it is missing the EMK or AED. By regulation, flight attendants may only use the equipment and medications under the direction of a licensed medical provider. For minor medical issues, flight attendants may use a simple "first aid" kit that is stowed separately without consulting a medical professional. The contents of an aircraft first-aid kit typically include[13]
  - Antiseptic swabs (10/packs)
  - Bandage adhesive strips
  - Bandage, gauze 7.5 cm $\times$ 4.5 cm

Fig. 1. United Airlines aviation emergency medical kit. (*Courtesy of* Healthfirst, Mountlake Terrace, WA and used with permission, Banyan Medical Systems, Inc.)

Table 4
Emergency medical kit required items

Contents	Quantity
Sphygmomanometer	1
Stethoscope	1
Airways, oropharyngeal (3 sizes): 1 pediatric, 1 small adult, 1 large adult or equivalent	3
Self-inflating manual resuscitation device with 3 masks (1 pediatric, 1 small adult, 1 large adult or equivalent)	1:3 masks
Cardiopulmonary resuscitation mask (3 sizes): 1 pediatric, 1 small adult, 1 large adult or equivalent	3
IV administration set: tubing with 2 Y-connectors	1
Alcohol sponges	2
Adhesive tape, 1-inch standard roll adhesive	1
Tape scissors	1 pair
Tourniquet	1
Saline solution, 500 mL	1
Protective nonpermeable gloves or equivalent	1 pair
Needles (2–18 gauge, 2–20 gauge, 2–22 gauge, or sizes necessary to administer required medications)	6
Syringes (1–5 mL, 2–10 mL, or sizes necessary to administer required medications)	4
Analgesic, nonnarcotic, 325-mg tablets	4
Antihistamine, 25-mg tablets	4
Antihistamine injectable, 50 mg (single-dose ampule or equivalent)	2
Atropine, 0.5 mg, 5 mL (single-dose ampule or equivalent)	2
Aspirin tablets, 325 mg	4
Bronchodilator, inhaled (metered dose inhaler or equivalent)	1
Dextrose, 50%/50 mL, injectable (single-dose ampule or equivalent)	1
Epinephrine 1:1000, 1 mL, injectable (single-dose ampule or equivalent)	2
Epinephrine 1:10,000, 2 mL, injectable (single-dose ampule or equivalent)	2
Lidocaine, 5 mL, 20 mg/mL, injectable (single-dose ampule or equivalent)	2
Nitroglycerine tablets, 0.4 mg	10
Basic instructions for use of the drugs in the kit	1

From FAA advisory circular. 2006. Available at: https://www.faa.gov/documentlibrary/media/advisory_circular/ac121-33b.pdf.

- Bandage, triangular, 100-cm folded and safety pins
- Dressing, burn 10 cm × 10 cm
- Dressing, compress, sterile 7.5 cm × 12 cm approximately
- Dressing, gauze, sterile 10.4 cm × 10.4 cm approximately
- Adhesive tape, 2.5-cm standard roll
- Skin closure strips
- Hand cleanser or cleaning towelettes
- Pad with shield or tape for eye
- Scissors, 10 cm (if permitted by applicable regulations)
- Adhesive tape, surgical 1.2 cm × 4.6 m
- Tweezers, splinter
- Disposable gloves (several pairs)

  - Thermometer (nonmercury)
  - Resuscitation mask with one-way valve
  - First-aid manual (an operator may decide to have one manual per aircraft in an easily accessible location)
  - Incident record form
- If the medical professional needs the kit, the flight attendant will procure it.
- The standard EMK may not be available on international flights with non-US carriers. The International Air Transport Association endorses the Aerospace Medical Association's recommendations, but does not regulate the contents of EMKs of international airlines.[35]

Automated External Defibrillators

- Before 1990, if there was a cardiac arrest on board, it was a standard airline practice to divert aircraft to the nearest major airport. If one considers the 20 to 30 minutes required for an emergency landing from cruising altitude, plus a 10-minute taxi time to the gate, it is clear that in the past, these patients rarely survived.
- The successful introduction of AEDs for use by personal outside of hospitals has resulted in vastly improved ventricular fibrillation survival rates.[36] These data have prompted many international airline organizations to introduce AEDs into their aircraft fleet.
- The FAA made it mandatory for all US-based commercial passenger aircraft with at least one flight attendant to carry on AEDs since 2001.[37]
- If an AED is on board, typically at least one cabin crew member will be trained in its use. Airline protocol requires a crewmember to manage the AED and assist or direct its use.
- If cardiopulmonary resuscitation (CPR) is indicated, begin CPR and ask the cabin crew to assist. One can expect that all cabin crew have been trained in basic CPR.
- Some on-board AEDs include an electrocardiographic display (monitor) that shows the cardiac rhythm. AEDs with monitoring capability are clinically useful because they allow better decision making when a passenger presents with chest pain, palpitations, dyspnea, or lightheadedness.[27,38]
- For monitoring only, a new device, the Tempus IC (Remote Diagnostic Technologies, Hampshire, United Kingdom), may be used by people with little or no medical training. It can monitor blood pressure, tympanic temperature, glucometry, oxygen saturation as measured by pulse oximetry, respiration and breath gas analysis, and electrocardiogram, and transmit these data to a remote physician for diagnosis.[39] It is being adopted by a few airlines at this time.
- A compact smart phone transducer, Kardia (AliveCor), is now available. The device allows monitoring of electrocardiogram when used in conjunction with a smart phone. Kardia's single lead electrocardiogram is comparable with Lead 1 of a standard electrocardiogram machines.[40]

Limitations of In-Flight Automated External Defibrillators

Limitations of in-flight AEDs include the following:

- Operator failure to deliver the shocks because of patient movements interfering with analysis[41]
- Operator turning off the AED prematurely
- Not following instructions to deliver shocks
- Not realizing that the AED leads are off
- Misreading the AED screen instruction to start CPR

- Vibrations of the aircraft while in flight; however, has not been borne out in real practice
- Some airlines only allow AED-trained cabin crew to operate on-board AEDs; volunteering health care professionals are often unfamiliar with the equipment and therefore less qualified than trained crew[42]

Approach to Patient Care During In-Flight Emergencies

- The isolated environment and unavailability of specialized equipment can make for a challenging experience. Maintaining a calm, competent, and professional demeanor can go a long way toward creating a less stressful environment for the patient, crew, and other airline passengers.
- Medical professionals should respond to a call only if they are a licensed, currently practicing medical provider.
- Be prepared to show a form of professional identification (eg, a medical license) that verifies your training.
- Do not respond if you have been drinking alcohol. If you have been drinking (eg, one drink) and no other provider responds, be sure to offer full disclosure to the flight crew and the patient.
- It is appropriate to ask the patient for consent before commencing in-flight care if they are not altered. This is generally best done with a crewmember as witness.[43]
- Ask for one flight attendant to continue assisting throughout the in-flight emergency. This helps to maintain continuity and ensures that you have access to needed equipment and cockpit communications.
- If the passenger seems to be severely ill, request ground-based consultation. On all US carriers and most international carriers you will have access to a ground-based consultant that greatly eases the pressure on any in-flight medical volunteer.
- You may legally speak to the flight crew about the medical issues.[29] The airline is not required to follow federal regulations regarding health care privacy, because airlines are not considered to be a covered entity as defined by HIPAA.
- History taking may be difficult because of language barriers. Family members or another available passenger may act as an interpreter. The flight crew may not offer this, and it may be up to you to request this via a simple cabin announcement.
- Obtain and record vital signs early in the event.
- Physical examination can be extremely limited because of limitations in space, vibration, and ambient cabin noise. Auscultation of the heart, lungs, or abdomen may be virtually impossible.
- Better conditions for the evaluation and care of a passenger may necessitate moving the patient to an open area, such as an aft galley. If a full resuscitation is indicated, such as bag mask ventilation or AED defibrillation, this can only be done with the patient moved to a larger area. Treating a patient in the aisle should be avoided when possible because it impedes normal flight crew operations.
- You may be able to find additional medical equipment from other passengers. For example, in the case of a suspected hypoglycemic or hyperglycemic emergency, ask the flight attendant to announce that you are in need of a glucometer, which a passenger with diabetes might have on board.
- Do not be afraid to request additional help. A common example might be a physician out of practice starting IV lines requesting an announcement for a nurse or emergency medical technician with IV skills. You should be ready to defer to

other providers who may have more experience delivering care in acute situations (ie, an office-based dermatologist deferring to an emergency physician).
- Do not to perform procedures that you are unfamiliar with.
- If the patient's presentation suggests a communicable disease, be sure to notify the cabin and/or flight crew.
- If you are presented with a "Do Not Resuscitate" order by an accompanying family member or friend, you need to make a decision on how to proceed. The cabin crew may decide to continue resuscitation if their company policy requires it, despite the Do Not Resuscitate order.[13]

DEATH ONBOARD

International Air Transport Association Guidelines for death on board (January 2016) state that cabin crew trained to perform CPR should continue CPR until one of the following occurs[44]:

1. Spontaneous breathing and circulation resume; or
2. It becomes unsafe to continue CPR (eg, heavy turbulence and/or forecasted difficult landing after liaising with the flight deck); or
3. All rescuers are too exhausted to continue; or
4. The aircraft has landed and care is transferred to EMS; or
5. The person is presumed dead. If CPR has been continued for 30 minutes or longer with no signs of life, and no shocks advised by an AED, the person may be presumed dead, and resuscitation ceased.

Airlines may choose to specify additional criteria, depending on the availability of ground to air medical support or an on board physician. According to some sources,[45] it may be prudent to avoid declaring death. This is because the legal implications of declaration of death vary from country to country. Therefore, limit involvement to advising the cabin crew regarding the presumption of death.

ON-BOARD MEDICAL OXYGEN (PORTABLE OXYGEN BOTTLES)

As stated in the Federal Aviation Regulations, 14 CFR 121.333 (E) (3)[46]:

> *For first-aid treatment of occupants who for physiological reasons might require undiluted oxygen following descent from cabin pressure altitudes above flight level 250, a supply of oxygen in accordance with the requirements of §25.1443(d) must be provided for two percent of the occupants for the entire flight after cabin depressurization at cabin pressure altitudes above 8000 feet, but in no case to less than one person. An appropriate number of acceptable dispensing units, but in no case less than two, must be provided, with a means for the cabin attendants to use this supply.*

Many airlines carry a minimum of one portable oxygen bottle (POB) per flight attendant, which equals or exceeds the FAA minimum oxygen requirement discussed previously.

Flow Rates and Duration

If called to assist in an on-board emergency, keep in mind that POBs may have only two fixed settings: high (4 L/min) and low (2 L/min) constant flow. Selection is made via a knob mounted on top of the regulator. Do not confuse these settings with "low" and "high" flow used in most emergency departments and hospitals, where high flow implies 10 to 15 L per minute (or higher). The so-called "high flow" setting on aviation

POBs is therefore considerably lower than what is normally used in EMS settings. Alternatively, some airline POBs are adjustable between 2 and 8 L per minute.

Personal Portable Oxygen Bottles

The FAA prohibits the use of personal POBs during flight because they contain compressed gas or liquid oxygen that is considered hazardous material. Airlines are allowed to carry a passenger's filled oxygen cylinder in the aircraft cabin[47] but the passenger cannot use it. However, because written pilot notification and additional HAZMAT training and manual documentation are required, most US airlines do not offer this service. Passengers should check with the specific airline before planning on carrying their own oxygen cylinder to their destination.

Liquid oxygen is classified by the FAA as a hazardous material. Therefore, the use of liquid oxygen systems on commercial aircraft is prohibited. If necessary a portable liquid oxygen system can be checked as baggage if the oxygen reservoir has been emptied.

Passengers requiring a constant supply of compressed or liquid medical oxygen are either not be able to travel, or may request, from a licensed physician, verification that they can complete their flight without the use of medical oxygen.

Carrier-Supplied (Compressed) Oxygen (Portable Oxygen Bottles)

Some airlines provide, for a fee, compressed bottled oxygen during flight as a service to passengers who need oxygen therapy. Equipment specifics (eg, flow rates and available equipment, such as masks) vary among airlines. Airlines typically do not provide oxygen for passengers before or after a flight (eg, between connecting flights). Some oxygen suppliers can arrange to have a representative meet a passenger with portable oxygen at the airport when they arrive. Because of the red tape associated with carrying compressed oxygen on board, and the availability of portable oxygen concentrators (POCs), few airlines offer bottled oxygen.

Personal Portable Oxygen Concentrator

The FAA has recently issued guidelines permitting the onboard use of certain POCs. Most airlines allow POC devices to be brought onboard.[48] Check with the specific airline to see which POC models are approved for use during flight.[49] The FAA maintains up-to-date reference materials on approved portable oxygen concentrators.[50] Unlike carrier-supplied oxygen, POCs can be used by passengers during long layovers or delays. Travelers can also continue to use POCs at their final destination without the necessity for additional arrangements. Notes concerning use of POCs include the following[51]:

- If the system is not an FAA-approved POC, it is not permitted on the aircraft.
- Because POCs are considered assistive devices, they are not counted as carry-on luggage.
- The POC user is responsible for supplying sufficient spare batteries to power the device for the duration of the flight, including a contingency supply for any unanticipated delays.
- POC batteries may be recharged during layovers; however, airlines do not guarantee travelers access to electrical outlets during flight. Travelers with powered POCs should request a seat that offers them access to an electrical outlet (if available).

Continuous Positive Airway Pressure Devices

Note that patients with sleep apnea may require use of their continuous positive airway pressure devices during long-duration flights.[51] Portable continuous positive airway pressure devices are classified as "medical assist devices" and are permitted on most domestic and international flights.

FUTURE CHALLENGES

Challenges to be addressed in the future include the following:

- Lack of standardization of the onboard EMK contents. The FAA standard EMK offers an important foundation, but EMKs adopted by airlines may contain dissimilar items based on the individual airline's particular medical practice.
- Lack of mandatory and standardized reporting system for a better understanding of the overall incidence of in-flight emergencies.
- Lack of postflight follow-up to ascertain frequency of nonemergency medical issues (ie, venous thromboembolism).
- The FAA requires flight attendants to undergo training in AED and CPR every 24 months[52]; however, there is no standardized training in medical protocols for onboard emergencies.
- Most airlines do not have clear standardized medical protocols for flight attendants managing in-flight medical emergencies. This includes protocols for flight attendants on flights where no medical professionals are available to volunteer.[53]
- Modern telemedicine technologies remain out of reach for most airlines despite recent advances in this field.

SUMMARY

The author aspires to the notion that after reading this article and experiencing the dreaded "if there is a doctor on board please press your flight attendant button" (or some variation), the reader will raise their finger toward the daunting flight attendant button secure in the confidence that the mysteries of the flight environment, resources, and expectations have been transformed into something more tangible and familiar.

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