Review Article

Current Concepts

Responding to Medical Events during Commercial Airline Flights

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THE provision of medical assistance to passengers during flights aboard commercial aircraft is a matter of concern to most physicians.[1-4] Although close to 2 billion people travel on commercial airlines each year, there has been little study of medical issues related to air travel.[1] As the number of air travelers increases and as the population ages, the number of medical events aboard commercial aircraft will increase. In this article, we review the environmental, clinical, and legal aspects of in-flight medical care aboard commercial aircraft.

EPIDEMIOLOGIC FEATURES

Incidence and Types of Events

Determining the incidence of in-flight medical events aboard commercial aircraft is difficult, because there are currently no regulatory reporting requirements. As a consequence, the available data are fragmentary. In the 1980s, two studies examined in-flight medical events among all the passengers arriving at two major U.S. airports. One of these studies reported an incidence of in-flight medical events of 1 per 33,600 passengers, and the other reported an incidence of 1 per 39,600 passengers — rates that correspond to about 33 and 30 in-flight medical events per day, respectively.[5,6] In 2000, a study by the Federal Aviation Administration (FAA) of 1132 in-flight medical events on domestic flights during 1996 and 1997 found a rate of 13 events per day.[7] This rate may be lower than those reported previously because only events serious enough to have involved ground-based medical support were included. Together, these results suggest that fewer than half the medical events that occur during flight are serious enough to require ground-based medical assistance.

The frequency of in-flight medical events aboard international flights is increasing[8-11] and was recently estimated to be one in-flight medical event per 14,000 passengers worldwide.[1] However, this estimate is probably high, since it would correspond to a rate of more than 350 events a day worldwide.

Most in-flight medical events are not serious.[5-13] Vasovagal episodes (fainting, near-fainting, dizziness, and hyperventilation) are the most common events. Cardiac, neurologic, and respiratory problems make up the most serious events and account for the majority of instances in which an aircraft must be diverted and make an unscheduled landing.[5-7,9,11-13] Table 1 summarizes the medical events commonly encountered aboard commercial aircraft.

Physicians' Participation

According to physicians' accounts[2-4] and the results of a 1998 questionnaire,[14] it appears that physicians are comfortable providing voluntary assistance during in-flight medical events. Fear of liability is cited as a major reason for physicians' reluctance to offer assistance.[14] In the 2000 study by the FAA,[7] 69 percent of all in-flight medical events aboard U.S.-registered aircraft were attended by a health care professional: physicians volunteered in approximately 40 percent of the instances, nurses in 25 percent, and paramedics in 4 percent. Moreover, there was 79 percent agreement between the in-flight medical diagnosis and the subsequent hospital diagnosis, and the passenger's condition improved in 60 percent of the cases, findings that suggest that the in-flight treatment provided was appropriate.[7]

Diversions

Unscheduled landings for medical purposes are a serious problem for commercial air carriers. Delays in reaching the final destination, inconvenience to passengers, added costs, and increased risks to safety make the decisions about diverting an aircraft complex and difficult. The cost of a medical diversion typically ranges from $3,000 to $100,000, depending on whether fuel needs to be dumped before landing and whether overnight accommodations for passengers are arranged.[11,15]

According to the 2000 report by the FAA, 13 percent of all in-flight medical incidents aboard domestic aircraft resulted in an emergency diversion. Cardiac incidents accounted for the greatest percent-

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Table 1. Common Medical Events aboard Commercial Aircraft.*

Type of Event	Study and Year		
	Cummins and Schubach,[6] 1989 (n=1107)†	DeJohn et al.,[7] 2000 (n=1132)	Dowdall,[9] 2000 (n=910)
	percent of all incidents		
Vasovagal	4	22	8
Cardiac	20	20	10
Neurologic	8	12	9
Gastrointestinal	15	8	28
Respiratory	8	8	5
Traumatic	14	5	3

*Percentages do not total 100 because not all types of events are listed.

†Data shown represent in-flight cases only.

age of the diversions (46 percent), followed in frequency by neurologic incidents (18 percent) and respiratory incidents (6 percent).[7]

ENVIRONMENTAL AND PHYSIOLOGICAL FACTORS

Cabin Pressure

A frequently overlooked fact is that during flight, the cabin pressure on commercial aircraft is usually adjusted to be equivalent to the barometric pressure found at an altitude of 1500 to 2500 m (5000 to 8000 ft) above sea level. Variations in cabin pressure within this range depend on the type of aircraft, weather conditions, and the need for passenger comfort in turbulent conditions.[16,17] These barometric pressures result in a decrease in the partial pressure of arterial oxygen from about 95 mm Hg to about 56 mm Hg in healthy passengers. This represents only a 4 percent reduction in the oxygen carried by the blood, since a partial pressure of oxygen of 56 mm Hg lies on the flat part of the oxyhemoglobin dissociation curve. However, in many passengers with cardiopulmonary disease, the partial pressure of arterial oxygen at sea level is lower than 95 mm Hg and is on the steep portion of the oxyhemoglobin dissociation curve, and at ordinary cabin pressures the oxygen saturation may fall dramatically.[8,18,19] For them, routine cabin pressures increase the risk of hypobaric hypoxia.[20-23]

Air and gas in body cavities expand in direct proportion to decreases in pressure, as described by Boyle's law. A cabin pressure equivalent to the pressure at an altitude of 1500 m results in expansion of air or gas volume by up to 30 percent.[16,18,24-26] In healthy passengers, gas expansion causes only minor abdominal cramping or aural symptoms. However, passengers who have recently undergone surgical procedures are at increased risk for wound dehiscence in conditions that cause gas expansion.[25]

Medical devices such as pneumatic splints, feeding tubes, urinary catheters, and cuffed endotracheal or tracheostomy tubes may be affected by the expansion of air or gas. Instillation of water rather than air can avert these problems.[18,19,27] Because of the potential adverse consequences of gas expansion, many commercial airlines do not allow the use of pneumatic splints aboard their aircraft. Plaster casts applied within 48 hours before flight should be bivalved to reduce the chance of circulatory problems.[27]

Cabin Air Quality

Many scientific studies show that the air in commercial aircraft cabins is safe and poses no risk to passengers.[28-31] However, the humidity in cabins is low, typically 10 to 20 percent.[19,25,32] This low humidity has the propensity to exacerbate reactive airway disease and trigger other minor problems, such as dryness of the eyes.

Little information regarding infectious diseases and their potential for person-to-person transmission in the cabin-air environment is available. Transmission of tuberculosis,[33,34] influenza,[1,35] measles,[36] smallpox,[1,33] cholera,[37] and enteritis[38,39] aboard commercial aircraft has been reported. The risk of cross-infection with airborne pathogens in aircraft cabins appears to be determined by the duration of the flight (with eight or more hours indicating an increased risk) and the proximity of the index passenger (with seating within two rows indicating an increased risk).[1,33,40] The Centers for Disease Control and Prevention and the World Health Organization have established guidelines on when and how to notify passengers and flight crew of the need for antimicrobial chemoprophylaxis after certain types of exposure.[40,41]

Violence aboard Aircraft

The incidence of disruptive behavior in an aircraft passenger, or "air rage," is on the rise and places flight crew and passengers at high risk for injury.[42] The number of in-flight incidents involving disorderly physical actions tripled between 1994 and 1997 aboard American Airlines alone,[43] and alcohol was implicated in 25 percent of all such incidents.[42,43] British Airways recorded 266 incidents in 1997 involving smoking, drunkenness, or abusive behavior. In some instances, physicians have assisted by chemically sedating agitated or violent passengers.[44,45] The recent increases in vigilance with respect to aircraft security have led to stricter penalties for violent or disorderly behavior aboard commercial aircraft.[1,42]

MEDICAL FITNESS FOR AIR TRAVEL

General Principles

Many passengers are unaware of the health implications of air travel. Physicians are increasingly expected to decide who is and who is not fit for air travel and to advise the public on matters relating to safe air travel. The Air Carrier Access Act of 1986 prohibits airlines from discriminating against passengers with disabilities, but airlines still have the right to refuse passengers who are not medically fit to travel on commercial aircraft.[46]

A patient with special needs, such as a need for supplemental oxygen, may require a medical certificate from a physician (preferably one with training in aviation medicine) stating that the passenger is medically fit for commercial air travel at a cabin pressure equivalent to that at an altitude of 2500 m.[19,21,27] FAA security directives established since the terrorist acts of September 11, 2001, allow syringes and needles (with cap guards) if the passenger has a documented medical need for such equipment. The passenger must also have in his or her possession the medication that necessitates the use of a syringe, and the medication must have a pharmacy label identifying it.[47]

There are numerous guidelines on air travel for persons with acute or chronic illnesses.[18-27,48-50] A partial list of contraindications to air travel is presented in Table 2. In general, travel on a commercial aircraft is contraindicated if a medical condition is adversely affected by hypoxia or pressure changes. A simple and useful test to assess a person's fitness for air travel is to determine whether he or she can walk 50 m (150 ft) or climb one flight of stairs without severe dyspnea or angina.[19,24]

Oxygen Therapy

Any passenger with a partial pressure of arterial oxygen of less than 70 mm Hg at sea level at rest requires supplemental oxygen during air travel.[19-21] Airlines have become familiar with transporting passengers with cardiopulmonary disease, and the use

TABLE 2. PARTIAL LIST OF CONTRAINDICATIONS TO COMMERCIAL AIR TRAVEL.*

CATEGORY	CONTRAINDICATION	SOURCE OF FURTHER INFORMATION
General	Low probability of surviving Any contagious disease Unstabilized behavioral problem	ASMA[19]
Cardiovascular	Myocardial infarction within previous 3 wk Unstable angina Coronary-artery bypass graft within previous 2 wk Decompensated heart failure Uncontrolled arrhythmias	Cummins,[17] AMA,[18] ASMA,[19] Alexander,[22] Harding and Mills,[24] Blumen et al.,[26] Bettes and McKenas[27]
Pulmonary	Contagious pulmonary infection Base-line partial pressure of arterial oxygen <70 mm Hg at sea level without supplemental oxygen Exacerbation of obstructive or restrictive lung disease Large pleural effusion Pneumothorax within previous 3 wk	AMA,[18] ASMA,[19] Gong,[20] Lien and Turner,[21] Harding and Mills,[24] Blumen et al.,[26] Bettes and McKenas,[27] Cheatham and Safcsak[48]
Neurologic	Cerebrovascular accident within previous 2 wk Uncontrolled seizures	AMA,[18] ASMA,[19] Blumen et al.,[26] Bettes and McKenas[27]
Surgical	Gastrointestinal, thoracic, otorhinolaryngologic, or neurologic surgery within previous 2 wk	AMA,[18] ASMA,[19] Blumen et al.,[26] Bettes and McKenas,[27] Cheatham and Safcsak[48]
Pregnancy-related	$\geq$35 weeks' gestation Complicated pregnancy	AMA,[18] ASMA,[19] Barry and Bia[49]
Pediatric	First week after birth	AMA,[18] ASMA[19]
Other	Severe anemia (hemoglobin level, <8.5 g/dl) Sickle cell crisis Decompression sickness	AMA,[18] ASMA,[19] Gong,[20] Lien and Turner,[21] Alexander,[22] Rosenberg and Pak,[23] Divers Alert Network[50]

*Adapted from guidelines of the Aerospace Medical Association (ASMA) with the permission of the publisher.[19] AMA denotes American Medical Association.

of in-flight therapeutic oxygen is increasing by 10 to 12 percent each year.[11] Supplemental oxygen for in-flight medical use can be arranged with commercial carriers but requires at least 48 hours' advance notice and a prescription for oxygen. Passengers cannot use their own equipment during flight, because oxygen is considered a hazardous material. Passengers are responsible for arranging for their own oxygen supply at their departure and arrival terminals.

MEDICAL LIABILITY

In general, airlines are legally liable for gross neglect or willful misconduct during in-flight medical events, as stipulated by international treaties.[51,52] The threat of lawsuits is one of the factors that has recently motivated airlines to improve their resources for handling in-flight medical events. To our knowledge, no litigation has been brought to date against a physician who has rendered assistance during an in-flight medical event. Does a physician who is a passenger have a duty to volunteer medical assistance? In the United States, Canada, and the United Kingdom, physicians do not have a legal duty to render assistance unless there is a preexisting physician–patient relationship. In contrast, many European countries and Australia do impose such a legal obligation.[51-53] By international law, the country in which the aircraft is registered has legal jurisdiction.[52-54] However, the country in which the incident occurs or the country of citizenship of the plaintiff or defendant can also have jurisdiction.[51-54]

An important step that reduced physicians' concern about liability was taken in 1998, when the Aviation Medical Assistance Act was signed into law.[55,56] The act provides limited "good Samaritan" protection to any medically qualified passenger who provides medical assistance aboard an aircraft.[55] In addition to being medically qualified, the assisting passenger must be a volunteer, render care in good faith, and receive no monetary compensation. Gifts in the form of travel vouchers, wine, or seat upgrades are not considered compensation. The assisting passenger must also render medical care similar to the care that others with similar training would provide under such circumstances. Physicians should be aware of the provisions of the Aviation Medical Assistance Act and recognize its limitations.

MEDICAL RESOURCES ABOARD COMMERCIAL AIRCRAFT

Emergency Medical Kit

Since 1986, the FAA has required all commercial aircraft with more than 30 passenger seats to carry an emergency medical kit.[56,57] Table 3 lists the contents of the emergency medical kit currently mandated by the FAA. In a recent reevaluation,[7] it was discovered that bronchodilator inhalers, oral antihistamines, and nonnarcotic analgesics obtained from other passengers were used frequently enough to warrant the inclusion of these items in the on-board medical kits,[7] and a final rule issued by the FAA in April 2001 required the addition of these items to the kits by April 2004.[57] Several airlines have augmented their on-board medical kits to include cardiac resuscitative medications, sedatives, diuretics, and intubation equipment. A basic first-aid kit containing adhesive bandages, dressings, elastic bandages, and splints is also available on board commercial aircraft to handle minor injuries.

Automated External Defibrillators

Evaluations of the use of automated external defibrillators on board U.S. commercial aircraft show survival rates ranging from 27 percent to 40 percent.[58-60] In general, automated external defibrillators analyze cardiac rhythm and automatically deliver a defibrillatory shock if ventricular fibrillation or rapid ventricular tachycardia is detected.[61] Some on-board automated external defibrillators have an electrocardiographic display that shows the cardiac rhythm. One study found on-board automated external defibrillators useful as cardiac monitors in that they allow better decision making in cases in which a passenger has chest pain, palpitations, dyspnea, or lightheadedness.[59]

According to the recent FAA ruling, all commercial aircraft traveling with at least one flight attendant must carry an automated external defibrillator by April 2004.[57] Many airlines have already voluntarily placed these devices on their aircraft and train flight attendants in their use. Several airlines allow only trained flight attendants — rather than volunteering physicians, who may be unfamiliar with the equipment — to attach and operate on-board automated external defibrillators.[62] Advanced telemetry systems that transmit video images, vital signs, 12-lead electrocardiograms, and oxygen-saturation data to ground-based physicians have been tested.[61] However, only one airline (Virgin Atlantic) has installed such systems on board its aircraft.

Ground-Based Medical Assistance

Many airlines no longer rely on the chance that a physician will be on board their aircraft if a medical event occurs. Flight crews on most major airlines now have direct links to some form of ground-based medical assistance. Several companies provide 24-hour, ground-to-air medical consultation and are staffed by physicians who are board certified in emergency medicine and have additional training in aviation medicine.

When contacted, the ground-based physician ad-

TABLE 3. ENHANCED ON-BOARD EMERGENCY MEDICAL KIT MANDATED BY THE FEDERAL AVIATION ADMINISTRATION.*

TYPE OF EQUIPMENT	ITEMS	QUANTITY
Currently required		
Diagnostic	Stethoscope	1
	Sphygmomanometer	1
Airway	Oropharyngeal airway	1 for children, 1 for small adults, 1 for large adults
Intravenous infusion	Syringes and needles	1 5-ml syringe, 2 10-ml syringes
	Gloves	1 pair
Medication	Nitroglycerin (0.4-mg tablet)	10
	Diphenhydramine (50 mg, injectable)	2 single-dose ampules
	Dextrose (50%, injectable)	1 50-ml ampule
	Epinephrine (1:1000, injectable)	2 single-dose ampules
	Instructions for use of drugs in kit	1
Required by April 2004	FDA-approved automated external defibrillator	1
	Mask for cardiopulmonary resuscitation	1 for children, 1 for small adults, 1 for large adults
	Bag-valve device	1 device with 3 masks
	Intravenous-infusion kit	1 set
	Normal saline (0.9%)	1 500-ml bag
	Aspirin (325-mg tablet)	4
	Diphenhydramine (25-mg tablet)	4
	Bronchodilator inhaler	1 metered-dose inhaler
	Epinephrine (1:10,000, injectable)	2 2-ml ampules
	Lidocaine (20 mg, injectable)	2 5-ml ampules

*This list was compiled from Federal Aviation Administration information.[57] FDA denotes Food and Drug Administration.

vises the flight crew, and any medically qualified passenger who volunteers to assist, on treatment. Although the ultimate decision to divert or not to divert the aircraft rests with the captain, the ground-based physician can provide medical advice on this point as well as information about diversion locations. At least one major airline maintains its own ground-based medical staff.

One possible advantage of the availability of ground-based medical assistance is that it may reduce unnecessary aircraft diversions. Such diversions are inconvenient and costly and often are not as safe as a routine landing at the planned destination. A 1997 study by the Air Transport Association found that ground-based medical assistance resulted in a 70 percent decrease in medical diversions.[63]

GENERAL APPROACH TO IN-FLIGHT MEDICAL EVENTS

There are no federal regulations or guidelines on the management of in-flight medical events, and each airline has its own policy. The flight crew is responsible for responding to a passenger who becomes acutely ill. The role of any passenger who is a health care professional and volunteers is to assist the flight crew with the medical event, not to take control.[64] Physicians should feel comfortable assisting during an in-flight medical event; fear of liability should not prompt reluctance to offer assistance. Medicolegal recommendations for physicians who respond to an in-flight medical event are presented in Table 4.

The goal of in-flight medical assistance is to stabilize the condition of the ill passenger until the aircraft has landed. The health care professional who volunteers to assist has several options for basic management: he or she may provide oxygen; use medications and supplies in the emergency medical kit; ask the flight crew to lower the altitude of the aircraft to increase cabin pressure; consult with and obtain advice from ground-based medical support personnel; and suggest diversion of the aircraft.[23,61]

Unresponsiveness in a patient warrants application of the automated external defibrillator (if available on board), use of oxygen, establishment of intravenous access, and administration of 50 percent dextrose. Angina should be treated with aspirin and nitrates. A bronchodilator should be considered for shortness of breath in a passenger with asthma or chronic obstructive pulmonary disease. Vasovagal syncope can usually be managed simply by raising the legs and applying cold compresses to the forehead. Acute allergic reactions can be managed with diphenhydramine and

TABLE 4. MEDICOLEGAL RECOMMENDATIONS FOR PHYSICIANS VOLUNTEERING ASSISTANCE DURING AN IN-FLIGHT MEDICAL EVENT.*

1. Properly identify yourself and state your medical qualifications. Some airlines require proof of your medical qualifications.
2. Obtain as complete a history as possible, inform the passenger and family members (if present) of your impression, and obtain consent before initiating any form of examination or treatment. Assume implied consent in the case of an incapacitated passenger.
3. If consent has been given, carry out an appropriate physical examination.
4. Request an interpreter if the passenger you are assisting does not speak your language.
5. Inform the flight crew of your clinical impression.
6. If the passenger's condition is serious, request that the aircraft be diverted to the nearest appropriate airport. On-ground medical support staff, if available, will help determine the best location for diversion.
7. Establish communication with on-ground medical support staff, if available. Respect the ground-based physician's expertise and experience in managing in-flight medical events.
8. Document in writing your findings, impression, treatment, and communication with the flight crew and on-ground medical support.
9. Do not use any treatment that you do not feel confident administering. Keep in mind that "good Samaritan" statutes protect you only from liability for actions that other competent persons with similar training would take under similar circumstances.

*Adapted from Newson-Smith[52] with the permission of the publisher.

(in severe cases) subcutaneous epinephrine. Increasing the cabin pressure, if possible, may alleviate altitude-related chest pain, shortness of breath, and abdominal pain by resolving relative hypoxia and decreasing the expansion of gas. An acutely agitated, psychotic, or violent passenger may be sedated with a benzodiazepine if it is available in the on-board medical kit.

A recommendation to divert the aircraft should be considered if a passenger has chest pain, shortness of breath, or severe abdominal pain that does not improve with use of the recommended initial interventions. A recommendation to divert should also be considered if a passenger is persistently unresponsive or has cardiac arrest, an acute coronary syndrome, severe dyspnea, stroke, refractory seizure, or severe agitation.

CONCLUSIONS

Providing emergency medical care to passengers during commercial air travel is challenging. There is now heightened interest on the part of both regulatory agencies and the aviation industry in medical events aboard commercial aircraft. Knowledge of the resources available to help deal with in-flight medical events is important both to passengers and to health care professionals who volunteer their assistance. Physicians should be prepared to assist during such events and to help by identifying those among their own patients who are at increased risk for medical events during air travel.

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