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Methods: We conducted a MEDLINE search using search terms relevant to aviation medical emergencies and flight physiology. The reference lists of selected articles were reviewed to identify additional studies.

Results: While incidence studies were limited by data availability, syncope, gastrointestinal upset, and respiratory complaints were among the most common medical events reported. Chest pain and cardiovascular events were commonly associated with flight diversion.

Conclusion: When in-flight medical emergencies occur, volunteer physicians should have knowledge about the most common in-flight medical incidents, know what is available in on-board emergency medical kits, coordinate their therapy with the flight crew and remote resources, and provide care within their scope of practice. [West J Emerg Med. 2013;14(5):499–504.]

In-flight Medical Emergencies

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Introduction: Research and data regarding in-flight medical emergencies during commercial air travel are lacking. Although volunteer medical professionals are often called upon to assist, there are no guidelines or best practices to guide their actions. This paper reviews the literature quantifying and categorizing in-flight medical incidents, discusses the unique challenges posed by the in-flight environment, evaluates the legal aspects of volunteering to provide care, and suggests an approach to managing specific conditions at 30,000 feet.

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INTRODUCTION

In-flight medical incidents during commercial air travel are common yet poorly understood and studied phenomena. The cramped quarters of an aircraft cabin environment and limited available resources make responding to such events fraught with challenging clinical decisions.

Despite the expansion of commercial air travel over recent decades, there are currently no guidelines for managing ill passengers during commercial flights from the standpoint of volunteer medical professionals. The incidence of these cases is hard to estimate given the paucity of available data. While commercial airlines often collect information on medical events during flight, they do not do so in a standardized format, so it is difficult to compare data across regions.

Equipment stocked in "emergency medical kits" is not mandated by any international aviation body, although the International Air Transport Association (IATA), the Aerospace Medical Association (AsMA), and the International Civil Aviation Organization (ICAO) have agreed upon standardized recommendations. Given the difficulties pertaining to epidemiological data described above, their contents are guided by anecdotal evidence and experts' opinions.

This paper discusses the unique characteristics of the flight environment, reviews the literature describing aviation medical incidents, and suggests an approach to managing these patients.

Flight Physiology

Air travel is associated with an assortment of potential stressors on the physical and psychological well being of travelers. Altitude changes and resultant fluctuations in cabin pressure in particular can affect susceptible airline passengers. A commercial jet's cruising altitude typically ranges between 29,000 and 39,000 feet. The Federal Aviation Administration (FAA) requires airlines to maintain cabin pressure below 8,000 feet, and a commercial plane traveling at 39,000 feet will usually maintain a cabin pressure at or below 7,874 feet.[1] When compared to the altitude of Aspen, Colorado, which is approximately 7,800 feet above sea level, it is not surprising

Table 1. Study characteristics and incidence of in-flight medical emergencies.

Authors	Journal	Dates	Study Design	Total # of Cases reported	Incidence	Diversion	Cardiac Arrest/Death
Hung et al	*Arch Int Med 2010*	01/2003-01/2008	Retrospective Cohort, Single Airline-Hong Kong	4068/5 years	Appx. 11.63 per billion revenue passenger killometers	46 (1.1%)	30 (0.7%)
Sand et al	*Crit Care 2009*	01/2002-12/2007	Retrospective 2 Airlines-Europe	10,189/ 5 years	Appx. 14 (+2.3) per billion revenue passenger kilometers	279 (2.7%)	52 (0.5%)
Baltsezack, S	*J Travel Med. 2008*	01/2006-01/2007	Retrospective Single Airline-Asia	191/1 Year	Not Analyzed	Not Analyzed	1 (0.5%)
Qureshi et al	*E Med Journal 2005*	06/2002-12/2002	Retrospective Single Airline- Edinburgh	507/6 months	Not Analyzed	Not Analyzed	Not Analyzed
Delaune et al	*Aviat Space Environ Med 2003*	07/1999-06/2000	Retrospective single airline.	2965/1 year	22.6 per million passengers	181 (7.9%)	7 (0.1 per million passengers).
Dowdall, Nigel	*BMJ 2000*	03/1998-03/1999-	Retrospective Single Airline-British Airways	3386/1 year	Appx. 1 per 11,000 passengers	Not Analyzed	Not Analyzed
Szmajer et al	*Resuscitation*	01/1989-12/1999	Retrospective Single Airline-Air France	380/10 years	1/20,000 passengers (during the last 2 years under review)	37 (9.7%)	3 (0.8%)
Cummins et al	*JAMA 1989*	09/1986-08/1987	Prospective Single airport	754/1 year	52.4 per million passengers.	7 (4%)	1 (1%)

that some passengers experience symptoms of altitude changes when flying.

According to Dalton's law, the total pressure of a system is equal to the sum of the partial pressures of its components. While the partial pressure of oxygen remains 21% throughout the atmosphere, atmospheric pressure drops at higher altitude resulting in a lower partial pressure of oxygen. At sea level, the partial pressure of oxygen is 160 mmHg, while at 8,000 feet it is 118 mmHg. The partial pressure of oxygen is further reduced when air is inspired into the lungs, which contains high concentrations of water vapor and carbon dioxide. The lower level of inspired oxygen results in less oxygen available for gas exchange and can lead to hypoxia.

The average person is usually able to ascend to a height of 7,800 feet without difficulty. People with cardiopulmonary co-morbidities, however, are more susceptible to changes in altitude. Patients with chronic obstructive pulmonary disease (COPD), interstitial pulmonary disease, or pulmonary hypertension are at an appreciably higher risk of developing symptoms of symptomatic hypoxia. Clinically, patients may appear to have dyspnea at rest, cough, weakness or drowsiness, anxiety or agitation, cyanosis, tachycardia, tachypnea or rales.[2-6] Other medical conditions may also be exacerbated by high altitude, including congenital and valvular heart diseases, symptomatic coronary artery disease, decompensated heart failure, sickle cell disease and obstructive sleep apnea.[2-6] While there are no studies on pre-flight medical screening of passengers, many sources advise primary care providers to screen patients for these disorders and provide advice prior to commercial air travel.[7,8] Patients with relative hypoxia at rest or with minimal exertion at ground level elevation should be advised to avoid air travel or travel with supplemental oxygen.

Incidence studies

We conducted a MEDLINE search in March 2010 using search terms relevant to aviation medical emergencies and extracted incidence studies and high quality topic summaries published between 1980 and 2010. Reference lists of selected articles were reviewed to identify additional relevant publications.

The incidence of medical incidents during commercial air travel is unknown. MedAire, a medical assistance company that provides remote assistance to several commercial airlines in the United States, responds to an average of 17,000 cases per year. Given the absence of a national (or international) registry of incidents, reported numbers of cases from individual airlines and telemedicine providers cannot be generalized to an overall estimation of incidence.

Table 1 demonstrates the wide range of estimates generated by analyzing data from single airports or carriers.[9-16] Most are retrospective cohort studies. Qureshi, et al,[13] in a study published in 2005, retrospectively studied data from a single international carrier and characterized 507 medical incidents reported over a 6-month period in 2002. Dowdal, et al,[9] also performed a retrospective study using a single airline over 1 year and found the incidence of medical incidents to be 1 per 11,000 passengers.

Multiple airline studies include the study by Sand et al,[11] which was a retrospective study of incidents from 2 European airlines over the course of 5 years, demonstrating an incidence of 14 incidents per billion passenger kilometers. This is comparable to the study by Hung et al,[10] a 5-year retrospective

Table 2. In-flight emergencies by diagnosis.

	Journal	Syncope	GI	CV	Neuro: Seizures, CVA, Dizziness, Headache	MS, Trauma	Resp	Alleric Rxn	Ob/ Gyn	Psych/ Intox	Other/ Unknown	Total
Hung et al	*Arch Int Med 2010*	---	---	0.239	0.391	--	--	--	0.13	---	0.24	4068
Sand et al	*Crit Care 2009*	5307 (52.1%)	1286 (12.6%)	675 (6.6%)	250 (2.5%)	359 (3.5%)	231 (2.3%)	222 (2.2%)	62 (0.6%)	616 (6.0%)	1,181 (11.6%)	10189
Baltsezack, S	*J Travel Med. 2008*	28 (14.6%)	68 (35.6%)	18 (9.4%)	9 (4.7%)	16 (8.4%)	13 (6.8%)	7 (3.7%)	3 (1.6%)	6 (3.1%)	168 (12.0%)	191
Qureshi et al	*E Med Journal 2005*	128 (25.2%)	40 (7.8%)	46 (9.1%)	1 (0.2%)	37 (7.3%)	69 (13.6%)	---	1 (0.2%)	3 (0.6%)	182 (35.9%)	507
Delaune et al	*Aviation Space, Environmental Med*	348 (15%)	271 (12%)	258 (11%)	254 (11%)	279 (12%)	251 (11%)	63 (2.8%)	31 (1.4%)	68 (3%)	66 (2.9%)	1889
Szmajer et al	*Resuscitation 2001* (Air France)	62 (16.3%)	59 (15.5%)	45 (11.8%)	35 (9.2%)	20 (5.3%)	14 (3.7%)	9 (2.4%)	15 (3.9%)	35 (9.2%)	86 (22.6%)	380
Cummins et al	*JAMA 1989* (1 year prospective from one airport)	7 (3.7%)	28 (14.7%)	37 (19.4%)	16 (8.4%)	26 (13.7%)	15 (7.9%)	---	4 (2.1%)	2 (1.1%)	55 (28.9%)	190

GI, gastrointestinal; *CV,* cardiovascular*; CVA,* cerebrovascular accident*; MS,* musculoskeletal*; Resp,* respiratory

cohort study that demonstrated an incidence of 11.6 cases per billion passenger kilometers.The variation of incidence, flight diversion, and cardiac arrest data underscores the need for standardized, system-wide reporting and data tracking.

Common In-Flight Medical Events

Table 2 provides a breakdown of the types of in-flight medical incidents reported.[9-16] Once again, the lack of standardized data sources and the overlapping categorizations become evident through the wide-ranging results. The table nevertheless highlights common complaints and alludes to the predominant organ systems affected by the in-flight environment. Syncope, gastrointestinal upset, and respiratory symptoms were among the common medical complaints reported. Chest pain and cardiovascular events were also noted, and these cases were often associated with diversion.[7,9]

The data presented by Sand et al[11] indicated that syncope was the most common type of in-flight medical emergency. Baltsezack et al[12] noted that gastrointestinal complaints were the most common. Qureshi et al,[13] demonstrated that the exacerbation of pre-existing diseases (usually respiratory) was the most common cause of an in-flight medical emergency, and syncope and respiratory conditions were the most common complaints. A study focused only on pediatric medical consultations requested from a single airline noted a high incidence of infectious disease complaints in addition to respiratory and neurologic symptoms.[17] Each incident described was likely the product of a combination of contributing factors, including patient co-morbidities, the flight environment, and alcohol and drug use or withdrawal.

What's Available in Flight?

The FAA requires all American commercial airlines weighing 7,500 pounds or more and serviced by at least one flight attendant to carry an automatic external defibrillator (AED) and an enhanced emergency medical kit. AED use during the commercial flight environment has been validated as safe and effective.[18] Flight attendants must be CPR and AED certified every 2 years.

The standard emergency medical kit on American commercial airlines, which is based on recommendations by the Aerospace Medical Association's (AsMA) Air Transport Medicine Committee, includes a stethoscope, bag valve masks, syringes and intravenous catheters in a range of sizes, and commonly used medications listed in Table 3.[19] Several medications are listed as drug types, including "bronchodilator," "antihistamine," and "analgesic," so the specific medication included may vary from one kit to another. Flight attendants are trained to be familiar with the contents of the kit, and its seal is examined during every pre-flight check and restocked after it is used. According to FAA regulations, a flight may not take off if it is missing the medical kit or AED. Flight attendants may only use the equipment and medications under the direction of a licensed medical provider. For minor medical complaints, flight attendants may use a "first aid" kit that is stocked separately. Physicians requiring additional equipment or medications (e.g. a glucometer) can ask flight attendants to make an overhead announcement requesting the items from other passengers.

All United States (U.S.) airlines are required to carry the standard kit and many supplement its contents with additional equipment and medications. There are, however, no international regulations requiring a complete kit to be available overseas. The International Air Transport Association (IATA) does not regulate the contents of emergency medical kits of international airlines, although it

Table 3. The emergency medical kit.

Medications
Epinephrine 1:1,000
Epinephrine 1:10,000
Antihistamine, inj.
Dextrose 50%, inj. 50 ml (or equivalent)
Nitroglycerin tablets or spray
Major analgesic, inj. or oral
Sedative anticonvulsant, inj.
Antiemetic, inj.
Bronchial dilator inhaler
Atropine, inj.
Adrenocorticoid steroid, inj.
Diuretic, inj.
Medication for postpartum bleeding
Normal Saline
Acetyl salicylic acid for oral use
Oral beta blocker
Equipment
Stethoscope
Sphygmomanometer
Airways, oropharyngeal
Self-inflating manual resuscitation device with pediatric, small adult, and large adult mask
CPR masks (pediatric, small adult, large adult sizes)
Syringes
Needles
Intravenous catheters & tubing
Antiseptic wipes
Gloves
Sharps disposal box
Urinary catheter
Venous tourniquet
Sponge gauze
Tape adhesive
Surgical mask
Flashlight and batteries
Thermometer (non-mercury)
Basic instructions for the use of medications in the kit

does endorse the AsMA's recommendations. An international study evaluating the medical kits stocked by 32 European airlines revealed a high degree of variability, with several kits evaluated to be inadequate to administer emergency care.[20]

A growing number of airlines use the services of remote emergency response centers. "MedAire," "The First Call," and the University of Pittsburgh Medical Center's "StatMD," for example, offer 24-hour consultations via call centers staffed by physicians. If medically trained passengers volunteer their assistance they should coordinate with cabin crew and a response center physician. If a call center physician is not available, the volunteer physician must work with cabin crew and can suggest treatment or diversion options.

Table 4. General approach to managing in-flight medical incidents.

Approach
Identify yourself and your training/expertise
Treat in the seat whenever possible; use of the aisle blocks mobility of flight crew
Document your findings and treatments administered
Communicate and coordinate with flight crew and ground resources
Do not attempt to practice beyond your expertise
Request access to the emergency medical kit
Use a translator if necessary

Medico-legal Issues

Federal legislation contained in the Aviation Medical Assistance Act of 1998 has provided limited protection and guidance for physicians and other medical professionals who volunteer their services during flight. Volunteers must be "medically qualified" and receive no monetary compensation in order to receive protection.[21]

The legislation states that "an individual shall not be liable for damages in any action brought in 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." To date there are no documented cases of a physician being sued for providing assistance during an in-flight incident.[7,22,23]

While physicians have no obligation under U.S. law to volunteer, one can argue that they have an ethical obligation to do so, especially if they are specifically trained to respond to undifferentiated medical emergencies.

Volunteer physicians should document their assessment and interventions administered using a standard airline medical incident form if available, or on a blank sheet of paper if a form is not available. If possible, the volunteer physician should request a copy of the medical document or form for their personal records. If a patient requires ongoing monitoring and therapy, the volunteer may need to stay by their side for the duration of the flight. Once the plane lands, the volunteer can hand over care to on-the-ground medical staff who can transfer the patient to an appropriate facility.

Approach to patient and guidelines

A 2002 article published in the *New England Journal of Medicine* by Gendreau et al,[22] offers recommendations for volunteer physicians faced with an in-flight medical incident. The authors' key points and others are outlined in Table 4. Table 5 outlines evaluation and management considerations

for specific in-flight medical incidents.

If the patient's condition is unstable and requires immediate formal medical attention, the physician may recommend diversion of the flight to the nearest airport capable of landing the aircraft and with access to appropriate medical facilities. The act of diverting a full aircraft to the nearest city is expensive, estimated to range between $3,000 and $100,000 depending on the size of the plane and costs of additional fuel and passenger re-routing, and has far-reaching consequences.[22] Diversion is usually made in consultation with ground-based medical expertise and should account for regional medical resources along the flight path. The final decision to make an emergency landing rests with the pilot in command. An article published by Ruskin et al[23] advised diversion for unremitting chest pain, shortness of breath, or severe abdominal pain. Grendreau et al[22] add stroke, persistent unresponsiveness, refractory seizures, and severe agitation to this list. A 2010 study reviewing 4 years of flight diversion data from Air Canada revealed that the majority of diversions occurred following cardiac complaints.[7] Regardless of the presenting symptom, in-flight or ground-based providers must assess a patient's stability and perceived medical condition based on the limited clinical information available and then make a risk-based recommendation. Factors affecting this decision include the differential diagnosis of the patient's condition, available in-flight resources, the patient's response to initial treatments, and ground resources along the flight path. International flights that traverse oceans or large tracts of sparsely populated land may have a lower threshold for diversion before crossing these spaces given the paucity of resources once they are entered.[7]

In the case of multiple volunteers or a severe incident requiring a team approach, health providers should introduce themselves, their level of training, and their specialty in order to determine who should take the lead role. In some cases, a sub-specialist physician (e.g. a neonatologist) should defer to other personnel (e.g. an ED nurse or advanced paramedic) when responding to incidents beyond the scope of their training and experience.

DISCUSSION

An aircraft in mid-flight is a unique environment in which to provide medical care. Any setting, be it a wilderness location, a ship, or at the scene of an accident, is associated with clear challenges and resource constraints that warrant academic study and guideline development. The specialty of emergency medicine focuses on the management, evaluation, and diagnosis of medical emergencies in a variety of environments including resource-limited settings. It is the only recognized medical specialty that takes a health systems approach to emergency care by incorporating the principles of triage, screening for life-threatening conditions, and pre-hospital emergency medical services. The specialty must therefore take a leadership role in the field of aviation medical emergencies.

Recent decades have witnessed an increase in the ease and accessibility of air travel, with a resultant rise in the number and diversity of aircraft passengers. Patients with chronic medical conditions should be screened by their primary care providers prior to air travel to determine their ability to endure the flight environment. Patients with significant pulmonary or cardiovascular disease should be counseled to avoid air travel when possible. When in-flight medical incidents occur, emergency physicians are ideally suited to respond given the breadth of their training, improvisational skills, and team leadership experience. Volunteer physicians should request access to the on-board emergency medical kit, coordinate their

Table 5. Approach to common in-flight medical incidents.

Syncope	Assess vital signs, cardiovascular exam, and neurological exam. Recommend diversion for hypotension, arrhythmia, or suspected stroke.
Altered Mental Status	Assess for toxidromes. Administer oxygen, establish intravenous access and administer normal saline and dextrose 50%.
Seizure	Clear space around passenger. Administer sedative/anticonvulsant (benziodiazepine if available). Provide supportive care during post-ictal period. Recommend diversion for status epilepticus.
Chest Pain	Assess vital signs. Perform cardiovascular and respiratory exam. Administer oxygen, nitroglycerin, and aspirin. Recommend diversion for arrhythmia, abnormal vital signs, or concern for myocardial infarction.
Respiratory	
a) Asthma Exacerbation	a) Administer inhaled bronchodilator and oxygen. Consider intravenous steroid for moderate to severe symptoms. Consider intramuscular epinephrine (0.3 to 0.5 ml of 1:1000 solution) for severe symptoms.
b) Suspected Pneumothorax	b) Perform needle thoracostomy for suspected tension pneumothorax (unequal breath sounds, chest pain, dyspnea). Recommend diversion.
c) Suspected Congestive Heart Failure	c) Administer oxygen, assess vital signs and establish intravenous access. Administer oral nitroglycerin and intravenous diuretic. Recommend diversion.
Allergic Reaction	For mild allergic reaction, administer intravenous antihistamine and corticosteroids. For severe allergic reaction/ anaphylaxis, administer intramuscular epinephrine (0.3 to 0.5 ml of 1:1000 solution).
Gastrointestinal	
a) Nausea/Vomiting	a) Administer antiemetic. Establish intravenous access and administer normal saline.
b) Diarrhea	b) Establish intravenous access and administer normal saline.
Pregnancy Complications	Assess vital signs and establish intravenous access. Recommend diversion for abdominal pain or vaginal bleeding.

therapy with the flight crew and remote resources, and provide care within their scope of practice.

Existing data on both the incidence and classification of in-flight medical events are limited by the lack of a central registry with standardized data collection. Such a data collection tool has been advocated for by several international aviation organizations and could inform the development of emergency medical kits, flight crew medical training, and passenger screening protocols.

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