Aviation medicine: challenges for telemedicine

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Summary

The number and seriousness of medical problems on passenger-carrying aircraft in flight are increasing. Medical incidents occur at a rate of approximately 10–50 per million passengers carried. Medical equipment carried on commercial aircraft is limited to three items: a first-aid kit, an emergency medical kit and sometimes an automatic external defibrillator. Telephone medicine, a lower level of telemedicine support, is well established for commercial air operations. The availability of satellite telecommunications on passenger-carrying aircraft permits more sophisticated forms of telemedicine. Recent telemedicine experiments have involved the transmission of three-lead electrocardiograms (ECGs), heart rate, blood pressure, arterial oxygen saturation, end-tidal CO_2, respiratory rate, body temperature and realtime video. The challenge is to demonstrate that such techniques are practicable, improve patient outcomes and are cost-effective.

Introduction

The number and seriousness of medical problems on passenger-carrying aircraft in flight are increasing. This may be partly due to the ageing population, together with more passengers with chronic medical conditions and perhaps flight-associated stress.

What is the nature of in-flight medical problems? The US Office of Aviation Medicine studied in-flight medical incidents on certain US commercial flights between 1996 and 1997[1]. There were 1132 medical events; the most common problems were vasovagal (22%), cardiac (20%), neurological (12%), respiratory (8%) and gastrointestinal (8%). Of the 1132 incidents, 145 (13%) resulted in an emergency diversion. Fifteen (13%) were fatal, the cause in all but two being a cardiac problem.

How often do such events occur? In 65 months from 1991, the Qantas airline carried 31 million passengers and reported 27 in-flight cardiac arrests, a rate of approximately one per million passengers carried. Twenty-one of these passengers had asystole and six had ventricular fibrillation[2]. Commercial aircraft statistics show that approximately 1000 lives are lost annually due to ventricular fibrillation[3]; airlines expect that better emergency care will both improve this mortality rate and reduce unnecessary flight diversions, which are very costly and can delay flights for hours[4].

Other common problems which may occur in flight include the so-called 'economy-class syndrome' and the 'nervous passenger syndrome'. The former, first described in 1988, is related to deep-vein thrombosis[5]. Although recent studies have disputed the relationship between deep-vein thrombosis and long-distance travel[6], the fact is that aviation specialists agree on the risk factors, which include dehydration and limited seating room (Table 1)[7]. Nervous passenger syndrome, also known as disruptive passenger syndrome, is often connected to excess alcohol consumption and aggressiveness exacerbated by the cabin environment (limited space, low oxygen levels and dehydration)[8].

Although medical incidents occur at a rate of approximately 10–50 per million passengers carried[1], the equipment carried on commercial aircraft is at present generally limited to three items: a first-aid kit, an emergency medical kit (EMK) and sometimes an automatic external defibrillator (AED). Only the first two items are compulsory.

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Table 1 Seat dimensions used by various airlines

Airline	Distance between seats (cm)	Seat width (cm)
British Airways	79	43
United Airlines	79	46
Iberia	82	45
American Airlines	81	46
Air France	81	41

Optimum distance, 86 cm; optimum width, 40 cm.
Source: http://www.el-mundo.es/cronica/2000/CR263/imagenes/pag15.pdf. Last checked 5 September 2001.

Ground support

Telephone medicine, a lower level of telemedicine support[9], is well established for commercial air operations. It is usually provided by connecting the aircrew by radio to the airline company's doctor or to a ground medical support organization. American Airlines uses its own team of doctors to assist with medical problems in the air; Northwest airline is linked to the Mayo Clinic; and Delta airline has a contract with the University of Pittsburgh Medical Center. However, most airlines choose to contract with companies specializing in telemedicine support for aircraft, such as MedAire.

MedAire takes calls from its client airlines either through a seatback telephone or by radio. In the event of a medical emergency, the MedAire physician recommends whether or not the pilot should consider a diversion. In such situations, MedAire uses its medical resource database[10], which provides information on airports, medical facilities and emergency response resources in more than 5000 cities worldwide. This ensures that flights can be diverted to sites with adequate resources to help the traveller.

Automatic external defibrillators

The American Heart Association and other organizations advocate the use of AEDs (Fig 1) by people other than paramedics and emergency medical technicians[11]. AEDs are decision-support devices that require relatively little operator training. They are designed to improve survival. Survival after ventricular fibrillation (the most common cause of cardiac arrest) is 74% if defibrillation is applied in the first 3 min[11] and decreases by about 10% for every minute that defibrillation is delayed[12]. When a cardiac arrest due to ventricular fibrillation is witnessed and a defibrillator is available, the survival rate is nearly 90%[13].

As a consequence, airlines started to install defibrillators on aircraft and to train attendants in their use,

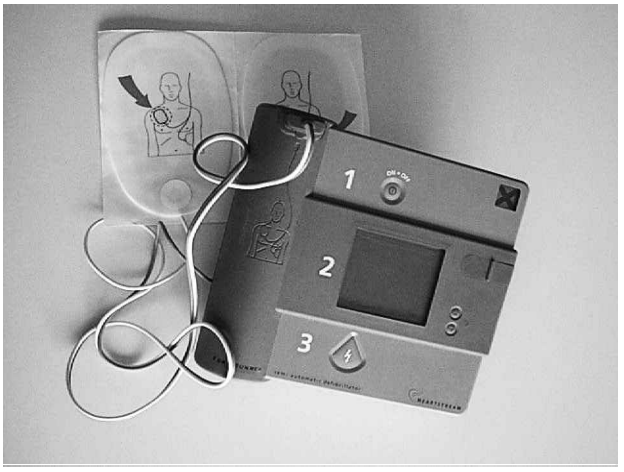

Fig 1 An automatic external defibrillator. (See http://www.saramedsales.com/forerunner.htm. Last checked 26 October 2001.)

even before the US Federal Aviation Administration (FAA) required aircraft with a flight attendant and with a maximum payload capacity of more than 7500 pounds (3400 kg) to carry an AED[14]. The result has been an improvement in passenger survival[15]. The use of an AED successfully treated the cardiac episode in five of the six Qantas passengers[2].

In the case of cardiac arrest on-board a commercial aircraft in flight, prompt diversion of the plane to a nearby major airport for definitive treatment has been progressively substituted by a more logical approach, which involves carrying AEDs on aircraft and training the cabin crew to use them and to give cardiopulmonary resuscitation. Since 1991, Qantas, as well as other international carriers, including British Airways, Virgin Atlantic and American Airlines, have installed AEDs. Flight attendants must, though, be properly trained to use the AED. The availability of AEDs to monitor cardiac rhythm and the additional data provided by the device allow further assessment of the status of the passenger and assist with the decision of whether to divert the aircraft[3] or use the EMK[15].

First-aid kits and emergency medical kits

Besides the AED, the other two medical items that are available in commercial aviation are the first-aid kit and the EMK. The first-aid kit is used by the flight attendant and contains bandages, scissors and non-prescription drugs. The EMK can be used by doctors on-board, but only with the aircraft commander's permission. Among other things, it contains: 50%

dextrose, glyceryl trinitrate tablets, parenteral diphenhydramine and adrenalin 1:1000. The contents stipulated by the European Joint Aviation Authority (JAA) for first-aid kits and the EMKs are summarized in Table 2 and Table 3.

El Al was one of the first international airlines to introduce an EMK on its aircraft. It has recently begun testing a new compact medical kit in which medications with a short shelf-life are stored in a compartmentalized tray that can be removed easily and replaced by a new tray. The tray contains a system to monitor the use of the medicines[16].

Other equipment that can be used in the air

At present, aviation telemedicine on commercial flights consists only of telephone support. However, the availability of satellite telecommunications on passenger-carrying aircraft permits more sophisticated forms of telemedicine. This includes telemetry, such as vital signs monitoring—arterial oxygen saturation, end-tidal CO_2, respiratory rate, body temperature, pulse, blood pressure and the electrocardiogram (ECG)[17,18]. Other aids, such as ventilators and pulse and blood pressure controllers, are also available for passengers, at least in principle. Companies specializing in such equipment include Aeromedix[19], Micromedical Industries Ltd[20], Medtronic Physio Control[21] and CIE Telemedicina[22].

Instrumentation specifically for use in the air is subject to certain design constraints. For example, ventilators should be designed to be tolerant to variations in cabin pressure at altitudes of up to 10,000 feet (3000 m) and must be electrically neutral to aircraft avionics. Particular care is necessary to ensure that changes in cabin pressure do not affect tidal volume and respiratory rate. Monitoring for ventilators used on-board is also essential, since sometimes the high ambient noise in the aircraft makes it difficult to identify patient or ventilator problems. Except in the case of Impact Instrumentation[23], whose Eagle-754 ventilator has automatic altitude compensation, none of the commercial ventilators, to our knowledge, have been specifically designed for in-flight use[24].

Legal environment

The international and legal principles that affect medical support in the air are based on the 'Good Samaritan principle', as well as guidelines from organizations such as the European Resuscitation Council[25] and the International Liaison Committee on Resuscitation[26], and aviation norms.

The Aviation Medical Assistance Act of 1998 implemented by the FAA included a 'Good Samaritan' provision to protect those who help in a medical emergency. It was designed to protect an individual (such as a passenger[27], pilot or flight attendant) from legal liability for helping in a medical emergency, unless that individual was guilty of gross negligence or wilful misconduct. The provision also protects the airline from liability in the case of a passenger who volunteers to help in a medical emergency; this protection is effective only if: the passenger is not an employee of the airline; and the airline, in good faith,

Table 2 Contents of first-aid kits on European airlines

Items	Medicines
Disposable resuscitation aid	Simple analgesics (paracetamol)
First-aid handbook	Anti-emetic
Ground/air visual signal code for use by survivors	Nasal decongestant
Bandages	Gastrointestinal anti-acid
Burns dressing	Anti-diarrhoeal medication
Wound dressing (large and small)	
Adhesive tape, safety pins and scissors	
Small adhesive dressings	
Antiseptic wound cleaner	
Adhesive wound closures	
Adhesive tape	
Splints, suitable for upper and lower limbs	
Disposable gloves	

Source: JAA regulations jar.ops.1.745. See http://www.espania.com/aspa/bibliot/jarops15.htm. Last checked 31 October 2001.

Table 3 Contents of emergency medical kits on European airlines

Items	Medicines
Syringes and needles	Coronary vasodilator (glyceryl trinitrate)
Oropharyngeal airways (two sizes)	Anti-spasmodic (hyoscine)
Tourniquet	Adrenalin 1:1000
Needle disposal box	Adrenocortical steroid
Catheter	Analgesic nalbuphine
Sphygmomanometer	Diuretic (frusemide)
Stethoscope	Antihistamine (diphenhydramine hydrochloride)
Disposable gloves	Sedative/anticonvulsant (diazepam)
	Medication for hypoglycaemia (hypertonic glucose)
	Anti-emetic (metoclopramide)
	Atropine
	Digoxine
	Uterine contractant (ergometrine/oxytocin)
	Bronchial dilator
	Anti-spasmodic drugs

Source: JAA regulations jar.ops.1.755. See http://www.espania.com/aspa/bibliot/jarops15.htm. Last checked 31 October 2001.

believed that passenger was qualified to provide that help (i.e. was a doctor, nurse or otherwise experienced in dealing with medical emergencies).

However, the 'Good Samaritan' provision does not relieve the carrier of liability if harm is caused to a passenger by an employee providing assistance. The airline has a duty to provide safe transportation to those who have paid for it.

Future challenges

More sophisticated forms of telemedicine may improve coordination between air and ground. This could allow preparation for urgent treatment in the ambulance when the patient arrives on the ground. Recent telemedicine experiments have involved the transmission of three-lead ECGs, heart rate, blood pressure, arterial oxygen saturation, end-tidal CO_2, respiratory rate, body temperature and realtime video[17,18].

The most important limitation in delivering treatment to patients with life-threatening medical problems on-board aircraft is the lack of advanced life-support devices. Under the best of circumstances, approximately 20 min is required for the diversion and emergency landing of an aircraft. Even when a plane is already on the runway, it may take 10–15 min to return to the terminal[15].

This review article has not considered the savings that might be brought by telemedicine in the air. This may be a simple equation involving variables such as: the average value of the benefit per consultation (in arbitrary units), the probability that a case will necessitate a telemedicine consultation, and so on. However, studying the cost-effectiveness of telemedicine and stand-alone support systems in the air is difficult, particularly because in-flight medical reports do not contain sufficient data for analysis[2]. This reinforces the need for an on-board standardized medical record, which could form part of future aircraft medical devices.

The challenge, therefore, is to demonstrate that sophisticated in-flight telemedicine is practicable, improves patient outcomes and is cost-effective.

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References

1 DeJohn CA, Véronneau SJH, Wolbrink AM, Larcher JG, Smith DW, Garret J. The evaluation of in-flight medical care aboard selected U.S. air carriers: 1996 to 1997. *Federal Aviation Administration and MedAire Report for the Office of Aviation Medicine, Federal Aviation Administration.* 2000. Available at http://www.hf.faa.gov/docs/cami/00_13.pdf. Last checked 3 September 2001
2 Rayman RB. Aerospace medicine. *Journal of the American Medical Association* 1998;**279**:1777–8
3 O'Rourke MF, Donaldson E, Geddes JS. An airline cardiac arrest program. *Circulation* 1997;**96**:2849–53
4 Bagshaw M. Telemedicine in British Airways. *Journal of Telemedicine and Telecare* 1996;**2** (suppl. 1):36–8
5 Cruickshank JM, Gorlin R, Jennett B. Air travel and thrombotic episodes: the economy class syndrome. *Lancet* 1988;**ii**:497–8
6 Kraaijenhagen RA, Haverkamp D, Koopman MM, Prandoni P, Piovella F, Buller HR. Travel and risk of venous thrombosis. *Lancet* 2000;**356**:1492–3
7 Kesteven PJ, Robinson BJ. Clinical risk factors for venous thrombosis associated with air travel. *Aviation, Space and Environmental Medicine* 2001;**72**:125–8
8 Borrillo DJ. Air rage: modern-day dogfight. Increasing incidents of 'disruptive passenger syndrome' seen by airlines as alarming trend. *FederalAir Surgeon's Medical Bulletin* 1999. Available at http://www.cami.jccbi.gov/AAM-400A/FASMB/FAS9902/airrage.htm. Last checked 3 September 2001
9 Ferrer-Roca O, Sosa-Iudicissa M. *Handbook of Telemedicine*. Amsterdam: IOS Press, 1998
10 http://www.medaire.com. Last checked 3 September 2001
11 Valenzuela TD, Roe DJ, Nichol G, Clark LL, Spaite DW, Hardman RG. Outcomes of rapid defibrillation by security officers after cardiac arrest in casinos. *New England Journal of Medicine* 2000;**343**:1206–9
12 Larsen MP, Eisenberg MS, Cummins RO, Hallstrom AP. Predicting survival from out-of-hospital cardiac arrest: a graphic model. *Annals of Emergency Medicine* 1993;**22**:1652–8
13 Hossack KF, Hartwig R. Cardiac arrest associated with supervised cardiac rehabilitation. *Journal of Cardiopulmonary Rehabilitation* 1982;**2**:402–8
14 http://www.airweb.faa.gov/Regulatory_and_Guidance_Library/rgFAR.nsf/MainFrame?OpenFrameSet. Last checked 26 October 2001
15 Page RL, Joglar JA, Kowal RC, *et al.* Use of automated external defibrillators by a U.S. airline. *New England Journal of Medicine* 2000;**343**:1210–16
16 Glazer I, Cohen S. A new compact medical kit on El Al passenger aircraft. *Aviation, Space and Environmental Medicine* 2000;**71**:77–80
17 MacDonald A, McNicholl BP, Wootton R. Transmission of medical data from an aircraft. *Journal of Telemedicine and Telecare* 1998;**4**:62
18 Gandsas A, Montgomery K, McKenas D, Altrudi R, Silva Y. In-flight continuous vital signs telemetry via the Internet. *Aviation, Space and Environmental Medicine* 2000;**71**:68–71
19 http://www.aeromedix.com/uses/aviation.html. Last checked 25 October 2001
20 http://www.micromed.com.au/29_news/30_newsreleases/releases/20010109.htm. Last checked 25 October 2001
21 http://www.medtronicphysiocontrol.com/company/customers.cfm. Last checked 25 October 2001
22 http://www.cie-sat.com/1cie.html. Last checked 25 October 2001
23 http://www.aarc.org/products_services/impact/impact.html. Last checked 25 October 2001
24 Saltzman AR, Grant BJ, Aquilina AT, *et al.* Ventilatory criteria for aeromedical evacuation. *Aviation, Space and Environmental Medicine* 1987;**58**:958–63
25 The 1998 European Resuscitation Council guidelines for automated external defibrillation by EMS providers and first responders. In: Bossaert L, ed. *European Resuscitation Council Guidelines for Resuscitation*. Amsterdam: Elsevier, 1998: 121–6
26 Bossaert L, Callanan V, Cummins RO. Early defibrillation. An advisory statement by the Advanced Life Support Working Group of the International Liaison Committee on Resuscitation. *Resuscitation* 1997;**34**:113–14
27 Newson-Smith MS. Passenger doctors in civil airliners—obligation, duties and standards of care. *Aviation, Space and Environmental Medicine* 1997;**68**:1134–8