The impact of flying on passenger health:

a guide for healthcare professionals

British Medical Association
Board of Science and Education

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This report provides doctors with an up-to-date summary of how commercial flying can impact on the health of passengers. Doctors are often asked to certify a patient's 'fitness to fly'. Therefore, guidance is provided that enables doctors, where possible, to provide informed and evidence-based advice to patients about their health and wellbeing during a flight. The document also provides information and guidance for doctors who may be required to assist in a medical emergency during a flight.

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Board of Science and Education

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Foreword

The Board of Science and Education, a standing committee of the British Medical Association (BMA), provides an interface between the medical profession, the government and the public. One major aim of the board is to contribute to the improvement of public health. It has developed a wide range of policies and provides information for the public and the profession on health related matters. A comprehensive list of the department's publications is given at the back of the document.

At the BMA's 2003 annual representative meeting the Board of Science and Education was asked to examine the impact of flying on the individual. In addressing this, the board decided to produce a report that provides doctors with an up-to-date summary of how commercial flying can impact on the health of passengers. Doctors are often asked to certify a patient's 'fitness to fly'. Therefore, guidance is provided that enables doctors, where possible, to provide informed and evidence-based advice to patients about their health and wellbeing during a flight. The document also provides information and guidance for doctors who may be required to assist in a medical emergency during a flight.

Healthcare professionals need to provide general travel advice to patients that relates to pre-flight, in-flight and post-flight conditions. This report looks specifically at the potential effects of flying on passenger health and wellbeing. Information concerning the avoidance of the major causes of morbidity and mortality associated with air travel, such as road traffic accidents, traveller's diarrhoea, malaria and HIV infection is not included.

Professor Sir David Carter
Chairman, Board of Science and Education
May 2004

Please note that this report is a guide for doctors and other healthcare professionals on issues relating to the impact of flying on passenger health and wellbeing – it is not intended to be a comprehensive text. Where appropriate, the reader is referred to specialist texts and websites for more detailed information.
The recommendations made in this report represent the views of the BMA and not necessarily those of the authors.

Contents

Acronyms

AED	Automated External Defibrillators
AHU	Aviation Health Unit
AHWG	Department for Transport Aviation Health Working Group
AMC	Acceptable Means of Compliance
AsMA	Aerospace Medical Association
BATA	British Air Transport Association
CAA	Civil Aviation Authority
CPAP	Continuous Positive Airway Pressure
DfT	Department for Transport
DVT	Deep Vein Thrombosis
EASA	European Aviation Safety Agency
ECAC	European Civil Aviation Conference
ECS	Environmental Control System
ENT	Ear Nose and Throat
FAA	Federal Aviation Administration
GMC	General Medical Council
HEPA	High Efficiency Particulate Air Filters
IATA	International Air Transport Association
ICAO	International Civil Aviation Organisation
JAA	Joint Aviation Authorities
RCOG	Royal College of Obstetricians and Gynaecologists
SARS	Severe Acute Respiratory Syndrome
SIGN	Scottish Intercollegiate Guidelines Network
TSA	Transport Security Administration
WHO	World Health Organisation
WRIGHT	WHO Research Into Global Hazards of Travel study

Introduction

The number of people taking flights has increased significantly in recent years. The International Air Transport Association (IATA) predicted a rise from 1.4 billion airline passengers in 1997 to two billion in 2003.[1] The World Tourist Organisation also predicted an 80 per cent increase in travel by all forms of transport to long-haul destinations between 1995 and 2010.[2-4, a]

The Office for National Statistics' omnibus survey found that 49 per cent of adults in the UK had travelled by plane at least once in 2001. Of these, 50 per cent had made one return trip by plane in 2001, compared with 26 per cent who had made two, and 6 per cent who had made more than six trips. Those aged 45-54 were the most likely to have flown, and those aged 75 and over the least likely.[5] The health risks to passengers associated with international travel range from minor symptoms to severe morbidity and death. Hand in hand with an increase in travel, a similar increase in travel-related morbidity can be expected.

This document is for doctors and other healthcare professionals, to help advise their patients of any health and wellbeing problems they might encounter during (and due to) travel by air. It identifies the main potential problems and provides a summary of how their effects can be minimised. The appendices and list of references, including website addresses, are provided at the end of the document to enable the interested reader to obtain further information.

Regulatory framework

One of the reasons for the high degree of flight safety is that flying is highly regulated. After the Second World War, allied states signed a convention obliging each country to impose a set of agreed minimum safety standards for international flight operations. Having signed the convention, states became members of a specialised agency of the United Nations, the International Civil Aviation Organisation (ICAO). The ICAO is a sister organisation to the World Health Organisation (WHO), and has the task of ensuring the safe and orderly development of international civil aviation[6] (for details on international and UK authorities involved in air travel and health see appendix I).

ICAO is primarily concerned with flight safety. This means operating an aircraft without damaging it, or people or property on the ground, ie without causing an accident. Apart from reference to on-board first aid and medical kits, ICAO pays little attention to health issues unless they affect safety. For example, the health of pilots is clearly important since they may have a condition that could detrimentally affect flight safety should they become incapacitated during flight. ICAO therefore specifies standards which determine whether a pilot is, or is not, medically fit to fly and his/her pilot's licence depends on the inclusion of a valid medical certificate.[7]

a Both these figures will have been affected by the September 11 attacks. In 2001, air traffic decreased by 2 per cent and a further 0.5 per cent in 2002 to a total of 1.61 billion. In addition, the war in Iraq and the severe acute respiratory syndrome (SARS) epidemic, caused a decline in traffic in 2003. However, IATA expects air traffic to increase by 4.9 per cent in 2004.

Recently, there have been legal challenges to the definition of an 'accident', in an attempt to include a deep vein thrombosis (DVT) that develops on board an aircraft, but so far these have not succeeded.[8] In this case the interpretation of the Warsaw Convention[b] is critical, because in accordance with this, airlines are liable for damage caused by accidents.

The BMA believes that policy should be introduced at a national and international level to ensure that passengers are not subjected to any unnecessary health risks when flying and that when risk is unavoidable, they have sufficient information to make an informed choice about their flight.

House of Lords select committee

A few years ago, concerns about the effects on health of travelling by air became more prominent and, in response to this, the House of Lords Select Committee on Science and Technology set up an inquiry to look into the subject of *Air Travel and Health*.[9] The committee received evidence from several dozen organisations and individuals, representing the airlines, manufacturers, pilots and cabin crew, scientists and regulatory authorities and published its report in November 2000. This is generally agreed to be the most authoritative and detailed study of aviation health issues yet written. Virtually every aspect of airline operations that could conceivably affect the health of passengers and crew was considered and, although the committee found 'no significant impact of air travel on health for the vast majority of travellers', they pointed out the lack of regulatory oversight where health (as opposed to safety) was concerned. They also recognised that, for some individuals, health risks were significant and there was a dearth of authoritative, relevant information for passengers and healthcare professionals on which to base decisions on fitness to fly.

Sources of information

Healthcare professionals and passengers are now faced with an enormous choice of information sources that refer to health and flying, mainly because of the ease of promulgating information on the world wide web and the appetite of the media for health related matters. Unfortunately, many websites and media reports provide a view, often biased, of one individual or a pressure group.

Reputable sources have their drawbacks, because terminology is not consistent between sites. For example, DVT associated with travel has been variably termed 'economy class syndrome', 'travellers' thrombosis' and 'immobility syndrome'. Further, because the exact risk of flying with a particular condition or the benefits of attempted prevention is often unknown, different advice can be provided on different sites. This document will refer to a number of information sources

b The Warsaw Convention was signed in Warsaw on 12 October 1929. Article 17 of the Convention states – 'The carrier is liable for damage sustained in the event of death or wounding of a passenger or any bodily injury suffered by a passenger, if the accident which caused the damage so sustained took place on board the aircraft or in the course of any of the operations of embarking or disembarking'.

which are believed to be reliable and should enable the healthcare professional to make an informed decision with respect to risk of travel. However, it should be borne in mind that there remains a degree of uncertainty about what risks exist, their extent and the most appropriate precautions to take.

Recommended information sources available on the internet

For healthcare professionals:

- Aerospace Medical Association (AsMA): Medical guidelines for airline travel (www.asma.org/Publication/medicalguideline.html).[10]

For passengers and crew:

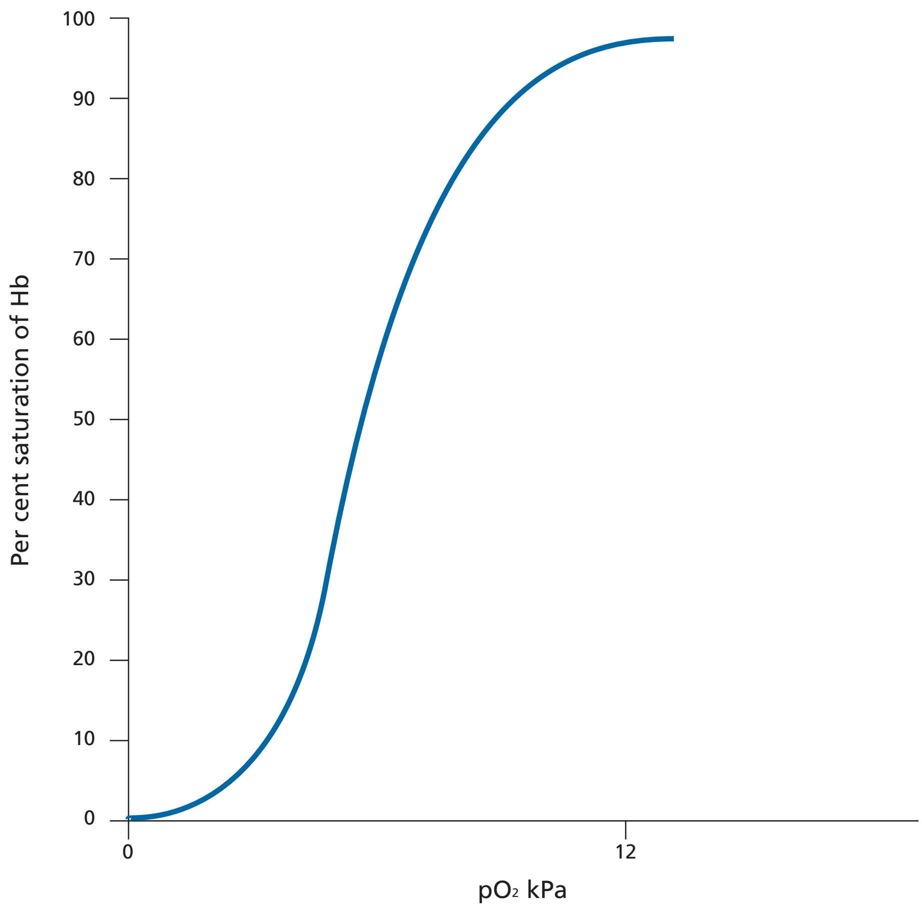
- UK Department of Health (www.dh.gov.uk)[11]
- WHO (www.who.int/ith/).[12]

Aviation and physiology: the fundamentals

Cabin pressure

Commercial aircraft fly at up to about 50,000ft (15,200m) above sea level, with most large airliners cruising between 35,000 and 40,000ft (10,500 – 12,000m).[13] Regulations require that the air pressure inside the cabin is not allowed to fall below a cabin altitude of 8,000ft (2,438 m) in normal operations.[c] For the vast majority of passengers, there is no evidence that there are any deleterious effects arising as a result of exposure to the maximum cabin altitude of 8,000ft. At this altitude the partial pressure of oxygen is approximately 120 mmHg (16.0 kPa[d]), 75 per cent of its sea level value of around 160 mmHg (21.3 kPa). Although this will lead to a fall in arterial oxygen tension from 95 mmHg (12.7 kPa) to 53-64 mmHg (7.0-8.5 kPa), the oxygen saturation will only fall from 97 per cent saturation at ground level to 85-91 per cent at 8,000ft (figure 1). These levels are well tolerated by healthy individuals, but may lead to hypoxia in individuals with medical conditions which impair the uptake, transport or delivery of oxygen to the tissues, including respiratory or cardiovascular disease, anaemia or infection.[13] Guidelines on fitness to fly are given later in this document.

Figure 1: Oxygen dissociation curve



c To make this possible, the aircraft's hull has to withstand a differential pressure between the outside air (low pressure) and the cabin air (relatively high pressure). Clearly it would be physiologically ideal if the air pressure inside the cabin could be maintained at a sea level equivalent, but this would require a much stronger and heavier hull and, consequently, higher fuel consumption and/or reduced capacity. There are also regulatory limits on the rate of change of cabin altitude on ascent and descent.

d 1 kPa = 7.5mmHg

Pressure and volume

As the aircraft climbs, the pressure inside the cabin decreases relative to sea level and gases expand in accordance with Boyle's Law (Pressure x Volume = Constant). At a cabin altitude of 8,000ft, the volume of a gas will have expanded by about 30 per cent. Similarly, as the aircraft descends for landing, the volume of a gas will decrease. These changes in gas volumes do not cause any problems where gas movement can take place freely, such as in the airways, but may cause discomfort or even tissue injury where gas is trapped or restricted.

Middle ear

The effects of these changes in gas volumes are most commonly seen in the middle ear. During ascent, air in the middle ear expands but the pressure within the space does not increase because air is able to escape along the Eustachian tube. This may occasionally be felt as a 'popping' sensation, but seldom causes discomfort. On descent, air must pass back along the Eustachian tube to equalise the air pressure as the air contracts. This process can be facilitated by yawning, swallowing or techniques such as the Valsalva manoeuvre, which involves attempting a forced expiration with the lips closed and the nostrils occluded by pinching the nose.[13]

On descent, the pressure in the middle ear becomes less than that in the outer ear if the Eustachian tube is obstructed. Most often this is due to inflammation from an upper respiratory tract infection. The tympanic membrane will then be pushed inwards, causing discomfort, injury or even perforation of the membrane. The paranasal sinuses can be damaged in the same way.

Lungs and abdomen

Other gas containing structures in the body include the lungs and the gut. Injury to the lungs is rare, but can occur due to expansion of gas trapped in bullae or a pre-existing pneumothorax.[14] Expansion of gas in the gut occasionally causes slight discomfort during ascent.

Post surgery

Iatrogenic introduction of gas into the body, for example in both laparoscopic and open abdominal surgery, can result in problems if air travel is undertaken before sufficient time has elapsed for the gas to have been re-absorbed. This would only take a few days in the case of laparoscopic surgery, but may take several weeks in some cases of intraocular surgery, depending on the gas used.[15] Doctors who carry out any procedure that involves the introduction of gas into a closed body cavity should advise patients on the length of time that should elapse before travel by air.

Decompression illness

The amount of nitrogen dissolved in body fluids and tissues is dependent on the ambient atmospheric pressure. As altitude increases and the atmospheric pressure decreases, nitrogen is released from solution and normally expelled through the lungs. Decompression illness occurs when nitrogen bubbles evolve rapidly in the tissues/blood vessels. These are thought to cause injury by occluding the microvasculature.

Decompression illness rarely occurs below 25,000ft (7,600m) and therefore is not a concern at normal cabin altitudes. However, it does occasionally occur in those who have been exposed to hyperbaric conditions prior to flight, for example divers and tunnel workers. Recommendations on the time that should elapse before flight vary, but typically sub-aqua divers are advised to allow a minimum of 12 hours between diving and flight, or 24 hours if the dive required decompression stops.[16]

Ozone

Ozone[e] in concentrations that may be found in aviation is an irritant and can cause minor eye, nose and chest symptoms in some individuals. The Federal Aviation Administration (FAA) has set a cabin air limit of not more than 0.1ppm of ozone for three hours, with a maximum of 0.25ppm at any time and these limits have been adopted within Europe by the Joint Aviation Authorities (JAA).[17,18]

Most ozone is converted to oxygen by the high temperatures that occur as air passes through the compression stages of the aircraft engine, prior to delivery into the cabin air supply, but it is possible for the amount entering the cabin to be sufficient to cause symptoms when flying through higher concentrations of ozone. The House of Lords Select Committee on Science and Technology recommended that, when aircraft are expected to fly through areas of higher ozone concentration, catalytic converters should be fitted to prevent any excess in the cabin.[9] Such catalytic converters are now fitted as standard on many modern aircraft and a recent survey undertaken for the Department for Transport Aviation Health Working Group indicated that all UK longhaul aircraft are fitted with catalytic converters.[19]

Cosmic radiation

Cosmic radiation comprises both solar (from the sun), galactic (from the galaxies) electromagnetic and subatomic particle radiation. The extent of exposure to cosmic radiation during a flight depends primarily on the altitude and route flown. Regulations are in place to restrict exposure of flight and cabin crew to cosmic radiation and some research has been conducted on the potential risks of this exposure (appendix II). However, this research is not conclusive. It is unclear whether the observed increase in incidence of some cancers are due to occupational exposure or non-occupational factors, such as reproductive history or lifestyle (see also section on pregnancy for guidelines for pregnant women).[20] The risk to most passengers who fly infrequently is not likely to be significant.[21] However, some frequent flyer business passengers may spend as many hours in the air as crew members[f] (for pilots, a maximum of 900 hours per year) and are therefore exposed to similar cosmic radiation doses. They should be advised to consult the expert sources given in this document.

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e Ozone (O_3) is formed during absorption of short wavelength ultraviolet light from the sun by oxygen. It is found at maximum concentrations at 100,000ft (30,000m), well above the cruising altitudes of airliners, but significant concentrations can occur at 40,000ft (12,000m). In addition, 'ozone plumes' are sometimes encountered, extending down to about 25,000ft (7,500m).

f The evidence on results of exposure of cabin crew is inconclusive – see appendix II

Summary: Aviation and physiology

- A cabin altitude of up to 8,000ft causes no deleterious effects for the vast majority of passengers. Reduced levels of oxygen may lead to hypoxia in individuals with medical conditions which impair the uptake, transport or delivery of oxygen to the tissues.[13]
- Changes in gas volumes during ascent do not cause any problems where gas movement can take place freely, such as in the airways, but may cause discomfort or even tissue injury where gas is trapped or restricted.
- There is no significant risk to most passengers from cosmic radiation (see section on pregnancy for advice for pregnant women).

Assessment of a passenger's fitness to fly

Doctors may find themselves being asked whether a particular patient is fit for travel by air, either prior to travel or following an accident or illness while away from home. Some airlines have a medical department able to provide advice for passengers. In many cases the doctor will be asked to complete a standardised IATA form known as the 'MEDIF' form, which ensures that a range of information relevant to air travel is provided (this form is downloadable at: www.iata.org/WHIP/_Files/WgId_0263/IATAReso700.pdf). In all situations, the BMA advises doctors to word statements on a patient's fitness to fly carefully, indicating the information on which the advice is based, rather than positively certifying a person's fitness. For example, 'I know of no obvious reason why this person should not fly' or 'there is nothing in the medical record to indicate that flying is risky for this patient'. This ensures that the doctor is not guaranteeing in any way that this patient can travel without any problem but rather saying that on the available evidence, there is nothing to indicate a greater risk for this person than for others. The doctor is partly dependent on what the patient chooses to disclose to them about past health problems.[22]

AsMA has published guidance for both passengers and healthcare professionals.[10,23] Other useful information for passengers can be found at the Department of Health and WHO websites.[11,12] In addition, many airlines provide information on their websites, which includes details about the availability of supplementary oxygen, wheelchairs and stretchers, as well as policies for travel by pregnant women. The British Airways website also includes a downloadable file intended for healthcare professionals, giving details of its policies on clearance of passengers with a range of medical, surgical and post-traumatic conditions.[24]

Healthcare professionals should be appropriately educated concerning the potential risks to health from flying. The BMA believes that undergraduate and postgraduate training curricula should include the relevant aspects. In-depth, specialised courses should be made available for those with a particular interest.

The main considerations in determining a passenger's fitness to travel

Will the passenger's medical condition be adversely affected by air travel?

As well as the effects of relative hypoxia and variations in cabin air pressure, consideration should also be given to factors such as:

- immobility
- the requirement to be able to adopt the brace position in an emergency and the confined/constrained environment
- the timing of any regular medication for those undertaking longhaul transmeridian travel.

Finally, it should not be forgotten that, for many passengers, the most strenuous and stressful parts of the journey are the travel to the airport, processing through security and passport control, the often long distance to the departure gate and the reverse process on arrival.

Will the passenger's medical condition adversely affect the comfort or safety of the other passengers and the operation of the aircraft?

Although the vast majority of people are able to travel safely by commercial aircraft, the airline (and the captain of the aircraft on the day) may refuse travel to any passenger who it considers may constitute a risk to the safe operation of the aircraft. Examples may include those who are suffering from contagious diseases, are moribund, are in the late stages of pregnancy or who present behavioural problems.

The young and the elderly: special considerations

The young

In general, infants and children present no particular problems when flying on commercial aircraft, other than perhaps behavioural issues associated with the prolonged periods of constraint on longhaul flights.

Infants and young children can experience more difficulties as a result of the changes in cabin air pressure, particularly on descent, as they may not voluntarily yawn or swallow to equalise middle ear pressure. Traditionally cabin crew used to distribute boiled sweets to encourage sucking/swallowing during descent. Now, more gentle rates of pressure change in modern aircraft lead to fewer problems. However, it may be helpful for parents to feed infants or provide them with drinks as the aircraft descends.

The elderly

As air travel has become a more widely available and accepted means of travel, changing demographics suggest that increasing numbers of elderly people will be travelling by air. Although there are no studies suggesting that age is in itself a barrier to air travel, such passengers are more likely to have problems associated with chronic illness or reduced mobility that requires consideration and planning prior to the journey.[g]

Pregnancy

There is generally no evidence that commercial air travel is hazardous in pregnancy, although there has been a recent report of a case of placental separation resulting from a seat belt injury during severe turbulence.[25, 26] However, an aircraft does not make a good maternity suite and most airlines impose restrictions on travel by women in the later stages of pregnancy. Typically travel is permitted up to the end of the 36th week for a woman with an uncomplicated single pregnancy, but it is important to check with the airline (and the travel insurance company) prior to travel. Earlier limits apply for multiple or complicated pregnancies and most airlines require a letter from the doctor or midwife, confirming the dates/history, from around 28 weeks. In the UK, the standard card used in shared ante-natal care would normally be sufficient for this purpose.

Some women may be concerned about the increased exposure to cosmic radiation. The additional radiation exposure to the foetus on a single flight is small and extremely unlikely to have any adverse effects. However, the decision on whether to accept this unquantifiable risk must lie with the woman herself. Further information is provided in the section on cosmic radiation and appendix II.

Pregnancy is also associated with an increased risk of DVT and the Royal College of Obstetricians

g The issue of adequate health insurance, although essential for all passengers travelling outside their country of residence, is particularly important for this group and others with chronic illness. Care must be taken to ensure that the cover includes the costs of treatment for exacerbation of existing conditions, repatriation (by air ambulance if necessary) and for return of the body in the event of death. Standard insurance policies may not provide appropriate cover.

and Gynaecologists (RCOG) has issued advice on measures that women should take to reduce the risk during air travel.[27]

Security, health and air travel

The security response to the increased threat of terrorism has created additional problems for passengers with some medical conditions. This is most apparent for those who wish to carry sharp items in their carry-on luggage, such as hypodermic needles for use by insulin dependent diabetics or for self-administration of low molecular weight heparin. In the US, the Transport Security Administration (TSA) has issued specific guidelines for acceptance of such items, which include requirements for a covering letter from the treating doctor and a pharmacy label on all medication.[28] In addition, quantities carried should be appropriate for use during the journey, with the balance being carried in hold baggage. Passengers wishing to carry such items should check with the airline prior to travel. It may also be wise to contact the airports, including any transit airports, as security at check-in is normally the responsibility of the airport, not the airline.

The other principal group who are likely to experience security problems are those with internal metalwork, such as artificial joints (which may set off the metal detectors) or cardiac pacemakers which, in some cases, may be affected by magnetic fields in detection devices. Again, a letter from the treating doctor may help to facilitate their smooth passage through security checks and the TSA advise passengers to notify screening staff of any such metalwork prior to passing through the detector.[28]

Finally, those who are taking regular prescription medication and travelling to other countries should always take a copy of their prescription with them. This will facilitate replacement of the medication if necessary, as well as assisting any treating doctors should the passenger become unwell while away from home. In addition, in the case of some medications and jurisdictions, it may help to avoid problems at Customs when carrying the drugs into the country.

Specific medical conditions

It is not possible in this report to give detailed advice on all the implications of air travel for all medical conditions.[h] This section provides information on a number of conditions of particular interest or importance; further advice and information may be obtained from the websites and studies referenced in the document.

h Healthcare professionals should be aware of those patients whose primary health condition may be exacerbated during a flight. Refer to the cited texts for further information.

Deep venous thrombosis

Concern about a possible association between air travel, principally longhaul travel, and DVT has been of particular interest to the media, politicians and researchers in recent years. Longhaul travel is associated with prolonged periods of immobility, a recognised risk factor for DVT. However, it is not known whether there are any factors specific to air travel that further increase the risk relative to other causes of immobility such as other forms of transport or sitting at a computer for long periods. Factors that have been suggested as of possible relevance include hypoxia, reduced barometric pressure, dehydration and cramped seating conditions. However, many of the studies carried out to date have been small, inconclusive or not repeatable, or have lacked adequate control groups. As an example, one study suggested an association between hypoxia and activation of coagulation.[29] A more recent paper addressed some of the criticisms of the earlier paper and concluded that there is no evidence that hypoxia has a major effect on coagulation in the general population.[30] There have been a number of recent reviews of the evidence.[31-33]

WHO research into global hazards of travel (WRIGHT) study

In August 2001, WHO announced proposals for a comprehensive research programme, the WRIGHT study, to fill key gaps in knowledge of the relationship between air travel and venous thrombosis.[34] The research aimed to determine the frequency of venous thrombosis, the magnitude of its association with air travel and the possible causal mechanisms involved. If a significant association was found, the studies would also provide clues on prevention strategies for air travellers, whatever their level of risk, with the aim of developing a set of recommendations. The estimated cost of the programme was 12 million Euros and the aim was to complete it over 2.5 years.

Obtaining the necessary funding for the programme proved difficult, but in May 2002 WHO announced the start of a reduced programme, with funding from the UK government and the European Commission.[35] This programme, which includes epidemiological, pathophysiological and clinical studies commenced in January 2003, with initial results due early in 2005. Pending the outcome of the WHO programme, doctors will continue to be faced with patients seeking advice on their individual risk of DVT and the need for preventive measures.

Information about DVT and travel

Information about DVT and travel is available from a wide range of sources. Many airlines provide information on this and other travel health issues on their websites and provide information to passengers before and during travel. A recent qualitative research study[36] was carried out on behalf of the Department for Transport Aviation Health Working Group (AHWG) and the British Air Transport Association (BATA). The result suggested that, while passengers appreciated the way in which the information was provided, they were less inclined to trust the airline advice than information from sources that were perceived as unbiased, such as the government. As well as previously mentioned sources (such as WHO, AsMA, Department of Health and RCOG websites) specific information and advice on DVT and air travel can be found on the NHS Direct and Scottish Intercollegiate Guidelines Network (SIGN) websites.[37,38]

Avoidance of immobility

Avoidance of immobility, either by walking around the cabin or the use of in seat exercises, is simple and seems safe. However, although such exercise has been shown to increase blood flow in the deep veins of the legs, this is not sustained once active exercise stops.[39] In addition, walking around the cabin may expose passengers to a greater risk of injury as a result of unexpected air turbulence. The use of hypnotics, especially if combined with excessive consumption of alcohol, could contribute to prolonged immobility if the passenger sleeps in a seated position and this should be discouraged.

Low humidity and dehydration

The low humidity environment of the aircraft cabin does not in itself lead to dehydration.[40] Excessive consumption of alcohol may cause dehydration, but there is no evidence that this is a significant factor leading to DVT. Advice to limit alcohol intake is sensible for a variety of reasons, but prevention of DVT may not be one of them.

Use of compression stockings

Several studies [41] have shown that compression stockings may reduce the incidence of leg vein thrombosis during longhaul flight, although the clinical significance of the findings is not clear and use of stockings may be associated with side effects. Most authorities now advise the use of compression stockings by those assessed as being at medium to high risk of DVT, but stress the importance of ensuring that these are correctly fitted so as to provide adequate compression.

Role of aspirin

The use of aspirin is perhaps the most controversial issue, with advice ranging from recommendation that its use is likely to be beneficial, through suggestions that it might help and is unlikely to be harmful, to clear statements that it should not be used. While there is good evidence for the value of aspirin in preventing arterial thrombo-embolic disease, its role in preventing venous thrombo-embolic disease is much less clear.

The pulmonary embolism prevention trial looked at 13,000 patients with hip fractures and showed a one-third reduction in the incidence of pulmonary embolus and DVT among the group taking aspirin at a dose of 160mg per day, for five weeks.[42] However, researchers applied this data to estimated rates of travel-related DVT and concluded that, at an estimated rate of 20 cases of DVT per 100,000 travellers, 17,000 passengers would have to take aspirin in order to prevent one case of DVT.[43]

This limited evidence of benefit must be balanced against the risk of harm. A Cochrane review of single dose oral aspirin for pain, with dosage ranging from 500mg to 1200mg, noted that approximately one patient in 40 would develop symptoms of gastric irritation.[44] A meta-analysis of 24 randomised controlled trials of long term aspirin therapy found an increased incidence of gastro-intestinal haemorrhage, even in the eight trials where low doses of aspirin (50-162.5mg/day) were used.[45]

In view of the clear risk of significant side effects and absence of clear evidence of benefit, patients should be advised against the use of aspirin just for the prevention of travel-related DVT.

Low molecular weight heparin

The use of low molecular weight heparin in the prevention of DVT in higher risk groups (including those who have previously had a DVT) is well established. However, it is not clear how it should be used in the prevention of travel-related DVT. Most authorities opt for an empirical regime of dosages on the day before travel, the day of travel and the day after travel. It should be remembered that cabin crew are generally not trained in the administration of drugs by injection and therefore the passenger, or an accompanying person, must be able to do this where necessary.

Aircraft seating

The issue of seating and available space, particularly in the economy cabin, was discussed in the House of Lords Science and Technology Committee report where it was indicated that more research is required.[9] The issue of seat pitch has been taken up by certain sections of the media (particularly in relation to DVT). There is no evidence that DVT is related to seat pitch and this is borne out by several papers which have noted that DVT occurs with comparable frequency in all classes of travel. Even in seats with the shortest seat pitch and the tallest passenger, there will still be room to flex the calf muscles – the relevant action to maintain venous circulation. For further details on aircraft seating refer to appendix III.

In defining the individual level of risk for development of DVT most sources offer similar advice based on common sense and on existing methods. The measures advocated range from avoidance of prolonged immobility, prevention of dehydration, use of compression stockings, aspirin and low molecular weight heparin. In all cases, except perhaps in the use of heparin, there is limited evidence of the value of these measures in relation to air travel.

Other cardiovascular conditions

Acute coronary syndromes and their treatment are some of the most frequent medical conditions requiring medical clearance before flight. One factor that makes judgement difficult, as indeed for many medical conditions, is the lack of an evidence base on which to make decisions. As a consequence, airlines may apply different guidelines, based often on their own anecdotal experience and the personal views of their medical advisers.[i]

Patients who have undergone cardiac, surgical or radiological intervention may, in uncomplicated cases, be fit for travel within a few days. For example, most patients are fit to travel three to five days following coronary angioplasty and two weeks following coronary artery

i As an example, a review of the aeromedical transport records of two international medical assistance companies concluded that it should be possible to carry patients, accompanied by a doctor, within two or three weeks after an acute myocardial infarction (MI). The medical clearance policy of British Airways permits unaccompanied travel just eight days after an uncomplicated MI, subject to satisfactory clearance using the MEDIF form for passengers less than three weeks post-MI (Cox G R, Peterson J & Bouchel L et al (1996) Safety of commercial air travel following myocardial infarction. *Aviation, Space and Environmental Medicine* **67**: 976-82).

bypass grafting. However, each case requires individual assessment, as any complicating features, such as arrhythmias or heart failure, are likely to delay travel until clearly controlled.

Patients with cyanotic congenital heart disease might be expected to be particularly vulnerable to the effects of the reduced partial pressure of oxygen in flight. Researchers investigated this[47] and concluded that adult patients may be able to tolerate commercial air travel well, without the need for taking supplementary oxygen. However, each patient should be assessed individually, to take account of any other factors such as uncontrolled rhythm disturbances or cardiac failure.

Respiratory disease

Passengers suffering from respiratory problems, either acute or chronic, might reasonably be expected to be the group most vulnerable to the effects of a hypobaric/hypoxic environment. Most, but not all, airlines are able to provide supplementary oxygen, for a fee, if this is pre-arranged. Flow rates available are typically restricted to 2l/min or 4l/min. The use of additional equipment, such as a continuous positive airway pressure (CPAP) machine by a passenger with obstructive sleep apnoea on a longhaul flight, will require prior discussion and clearance by the airline. Where such equipment is permitted, it will usually have to be powered by dry-cell battery and use will not be allowed for take-off and landing.

In 2002, the Air Travel Working Party of the British Thoracic Society published a series of recommendations on the management of patients with respiratory disease who wished to travel. These remain the best available source of guidance.[48] The Working Party emphasised the lack of clear evidence on which to base recommendations. They advised pre-flight assessment for a range of conditions, with particular caution in the assessment of those patients who are hypoxaemic at sea level:

- severe chronic obstructive pulmonary disease or asthma
- severe restrictive lung disease
- cystic fibrosis
- patients within six weeks of hospital discharge following acute respiratory illness
- recent pneumothorax
- co-morbidity with other conditions likely to be worsened by hypoxaemia
- pre-existing requirement for oxygen or ventilator support (including CPAP)
- pulmonary tuberculosis (once on treatment and confirmed as non-infectious)
- history of in-flight respiratory symptoms.

Depending on the circumstances, they advocated assessment by one of three methods:

- **Exercise tolerance.** Many airlines use the ability to walk 50 metres on the flat or climb a single flight of stairs at a reasonable pace, without stopping and without undue distress, as evidence that a passenger is likely to tolerate the aircraft cabin environment. Although simplistic and without formal evaluation, this test is a reasonable guide and is sufficient to allow the GP to provide appropriate advice in most cases.
- **Use of predictive equations.** There are a number of equations that may be used to predict in-flight oxygen saturation (SaO_2) or the partial pressure of oxygen in the plasma phase of the arterial blood (PaO_2) from sea level values. Although not absolutely accurate, these can be used to identify those patients who either clearly do or clearly do not require in-flight supplementary oxygen.
- **Hypoxic challenge test.** The preferred test is to subject the patient to a hypoxic challenge test in a hypobaric chamber. However these chambers are not widely available and therefore such tests are more frequently carried out using a simulated environment, breathing 15 per cent

oxygen at sea level. Even this method requires the resources of a respiratory laboratory and may not be readily available for most cases. In addition, the test is usually continued for only a limited time and may not be a true guide to the effect of exposure over a prolonged period on a longhaul flight. It should be reserved for patients whose requirement for in-flight oxygen is unclear, ie those with SaO_2 of 92-95 per cent and one of a number of additional risk factors. In practice, it may be easier for such passengers to request in-flight oxygen as a precaution, unless they have flown previously without difficulty.

Ear nose and throat (ENT) disorders

As discussed earlier, the changes in cabin altitude on ascent and descent, with consequent changes to gas volumes will affect parts of the body where gas is unable to move freely.

Problems are most frequently encountered in passengers suffering from simple upper respiratory tract infections who are unlikely to have considered the implications when deciding to continue with their journey. Painful ears or facial pain on descent are the likely consequences, and perforation of the tympanic membrane is an occasional complication.

Passengers who have experienced symptoms on an outward flight and are not sure whether to continue with their booked return flight, or have had problems on previous flights and are not sure whether to travel by air in the future, may consult their doctor. Recurrent barotrauma is likely to result in more significant or prolonged damage, although it is unlikely to lead to permanent damage. Generally, passengers should be advised not to travel by air until their symptoms have resolved and the middle ear appears normal. A positive Valsalva manoeuvre (observed through the auriscope as movement of the tympanum) is useful reassurance of normal Eustachian tube function.

Those who have more chronic problems, such as recurrent sinusitis or chronic serous otitis media, may require assessment by an ENT surgeon. Surgical treatment may be necessary and any procedure that allows free movement of gas, such as insertion of grommets or antrostomy, will allow air travel to be undertaken safely.

Diabetes

Travel by air does not have any direct consequences for those with diabetes. However, those diabetic passengers who are treated with insulin or oral hypoglycaemic drugs do need to give some thought to their travel plans.

This is particularly important for those who use pre-prandial short-acting insulin as part of their regime. Some people are reluctant to administer their insulin in the rather public and confined space of the aircraft seat and may inject insulin in a toilet in the departure lounge, in anticipation of a meal soon after take-off. Delays in departure or unexpected turbulence may delay the service of the anticipated meal and result in hypoglycaemia. Ideally, the passenger will have anticipated the possibility and will have carried a suitable snack. Where this is not the case, they should alert the cabin crew to their predicament as soon as possible so that an appropriate snack or early meal service can be provided.

Diabetic passengers who are undertaking transmeridian travel should also discuss their treatment regime with their medical advisers as soon as possible. In general, they are advised to continue on their home time and regime during the flight and only change to local time on arrival at their destination. Passengers with diabetes should however, obtain individual advice – it may not always be appropriate to follow the general recommendation to stay on home time. Further advice is also available from Diabetes UK.[49]

Finally, those using insulin should be reminded of the need for safe disposal of needles (although most diabetics have integral pen units). Each year cabin crew, cleaners, other airline staff and, occasionally, other passengers suffer needlestick injuries from hypodermic needles thoughtlessly discarded in seat pockets, seat cushions and toilet waste bins. Although passengers should make their own arrangements for safe disposal of needles, most airlines include sharps boxes in their medical kits and cabin crew will assist if asked.

Psychiatric disorders and behavioural disturbance

Passengers suffering from acute psychiatric disorders, ranging from severe flying phobia and anxiety to florid psychosis, may represent a danger to themselves and to the safe operation of the flight. In addition, in the current heightened awareness of the threat from terrorism, crew or fellow passengers may misinterpret any abnormal behaviour.

As a consequence, airlines generally adopt a very cautious approach when considering travel by passengers with a recent history of an acute illness or a previous history of flight related problems. In the case of a recent psychotic episode, they will usually require the condition to be stabilised on medication (the use of sedation to permit travel will seldom, if ever, be sanctioned) and insist that the passenger is accompanied by a competent escort, such as a registered psychiatric nurse.

Fear of flying

Fear of flying is estimated to affect 10-25 per cent of the population.[50] Symptoms range from mild anxiety to avoidance behaviour, with no clear cut borderline between 'normal' and 'pathological' fear, and those who seek help are those whose lives are severely affected by their avoidance behaviour.[51]

Most affected individuals are treated with behaviour therapy, often with educational input on the mechanics of flying, pilot training, aircraft noises and the effects of factors such as turbulence. They usually also include an aircraft flight. Researchers contacted 212 airlines and treatment facilities to request information on such programmes and were able to review 15 of 43 in detail.[52] All of these programmes shared the two elements of an information component and a test flight, but little evidence of efficacy was available. However, other authors have reported studies showing that these interventions are both effective and sustained.[53,54] Recently there has been considerable interest in the use of virtual reality exposure and some studies have reported sustained success rates comparable to those obtained using real flights.[55,56]

Courses in the UK for those affected by fear of flying include those that have flights in an aircraft and another which simulates flight experience.[57-59]

Air rage

Air rage, involving unruly disruptive or violent behaviour by passengers, is a topic that has attracted considerable attention in recent years. In managing such incidents, cabin crew are trained to be aware of the possibility of an underlying medical cause, such as hypoglycaemia in a diabetic or hypoxia in an elderly person with cerebrovascular disease. They are also trained in techniques aimed at reducing confrontation and defusing the situation, as well as in the use of restraint where necessary.

IATA helped airlines to address this issue, by publishing Guidelines for handling disruptive/unruly passengers in 1999. IATA has also produced a model Memorandum of understanding, to be used as the basis for an agreement between airlines and control authorities at airports on the application of legal processes in dealing with incidents.[60]

Doctors or other healthcare professionals travelling on aircraft where such incidents occur should be careful when volunteering to assist. In particular, they should avoid administering sedative drugs, as the individual may already have taken other medication or illicit drugs. Death has occurred as a result of drug interaction in such cases.

UK airlines have been reporting such incidents to the Civil Aviation Authority (CAA) since 1999 and the UK Deptartment for Transport has published the figures and analysis on its website.[61] In the period April 2002 to March 2003 there were 648 reported incidents that were classified either as 'significant' (613) or 'serious' (35) in all flights by UK airlines.

Of the 648 incidents, excessive consumption of alcohol and smoking-related difficulties were the two main contributory factors to disruptive behaviour. One commonly held belief is that alcohol has a greater effect when flying, as a consequence of the mild hypoxia. However, research published in 1988 showed that this is not the case.[62] Smoking, or the desire to smoke, featured in 260 incidents (40% of the total). Of these, 85 per cent involved smoking in the toilet compartment. This implies a degree of premeditated deception and poses particular safety risks if a carelessly discarded cigarette causes a fire.

It is important to keep these figures in perspective. During the 12-month period covered by the data, UK airlines operated about 1.2 million passenger flights and carried about 118 million passengers. This means that the chance of an individual passenger boarding a flight on which a serious incident took place was around one in 36,000, and that only one in every three million passengers was the cause of a serious disruptive incident.

Summary: Assessment of a passenger's fitness to fly

- In general, infants and children present no particular problems when flying on commercial aircraft. It may be helpful for parents to give infants food or drinks as the aircraft ascends/descends.
- Although there are no studies suggesting that old age is in itself a barrier to air travel, older passengers are more likely to have problems of chronic illness or reduced mobility, requiring consideration and planning prior to the journey.
- Travel will usually be permitted up to the end of the 36th week for a woman with an uncomplicated single pregnancy, but it is important to check with the airline prior to travel. Earlier limits apply for multiple or complicated pregnancies.
- The security response to the increased threat of terrorism has created additional problems for passengers with some medical conditions, for example, those wishing to carry sharp items.
- There is limited evidence of the value of the measures advocated for prevention of DVT in relation to air travel, except perhaps in the use of heparin.
- There is a lack of evidence on which to base decisions about medical clearance and much depends on individual professional judgement.
- The British Thoracic Society has published a series of recommendations on the management of patients suffering from respiratory conditions who wish to fly.
- Passengers suffering from simple upper respiratory tract infections should be advised to check with their GP whether medication pre flight may help. An ENT surgeon should assess those who have more chronic problems, such as recurrent sinusitis or chronic serous otitis media.
- Diabetic passengers who are treated with insulin or oral hypoglycaemic drugs need to give thought to their travel plans with regard to their treatment and regimen.
- Passengers suffering from acute psychiatric disorders may represent a danger to themselves and to the safe operation of the flight. As a consequence, airlines generally adopt a very cautious approach when considering travel by passengers with a recent history of acute illness or past history of flight related problems.
- Most cases of fear of flying can be treated with behaviour therapy.
- Doctors or other healthcare professionals travelling on aircraft where an incident of air rage occurs should be careful when assisting. They should avoid administering sedative drugs, as the individual may already have taken other medication or illicit drugs.

Communicable diseases on aircraft

Airborne disease

The available evidence indicates that transmission of airborne disease on board aircraft is uncommon and, when it does occur, it is usually a consequence of contact and droplet spread resulting from close proximity of groups of people. Such conditions are not unique to air travel and the risks are similar to those associated with other situations where people congregate (for further details on the aircraft cabin environment see appendix IV).

Concerns about transmission of disease during flight have been raised by media reports of the transmission of tuberculosis and other respiratory diseases, including the role of air travel in the severe acute respiratory syndrome (SARS) outbreak in 2003. However, studies of cabin air have shown that the microbial content of the cabin air supply is similar to that of homes and offices.[63] One study examined symptoms of the common cold among passengers who had flown seven days earlier. Approximately half of the passengers had flown on aircraft using 100 per cent outside air for ventilation and the remainder had flown on aircraft using recirculation systems. They found no difference in the incidence of newly reported symptoms between the two groups.[64]

Incidents of possible transmission of airborne infectious diseases that have been reported include:

- an outbreak of influenza in 1979 among passengers on board an aircraft held on the ground for three hours before take-off
- a case report of possible air travel related meningococcal disease; epidemiological investigation of measles transmission
- a study by the US Centers for Disease Prevention and Control of seven incidents of travel by a person (six passengers and one cabin crew) subsequently identified as suffering from 'open' tuberculosis.[65-69a] Evidence of transmission occurred in only two cases: in the first, this was limited to crew members whose exposure had been for at least 12 hours, and in the second to passengers seated in close proximity to the index case for over eight hours. There have been no subsequent reports of any of the contacts developing active disease.

Even without high efficiency particulate air (HEPA) filters, the progressive dilution of cabin air and its removal overboard by the environmental control system (ECS) greatly reduces the concentration of infectious organisms from that found in the immediate vicinity of the infected individual. However, in the unusual circumstance when the ECS is not functioning for an extended period (this can occur only on the ground) the House of Lords recommended that procedures should be put in place to reduce the risk of cross infection (and increase passenger comfort).[9] There are, however, serious logistical problems should passengers need to disembark then re-embark at short notice. Further, in the terminal building there is a continued risk of cross infection.

The SARS outbreak in 2003 highlighted the potential for air travel to facilitate the rapid spread of infectious disease around the world. The key problem was posed by passengers who were usually asymptomatic but incubating the illness. There was considerable concern at the time that transmission could occur on board and IATA worked closely with WHO (and ICAO) to issue advice and guidance to airlines. In the event, analysis showed that transmission only occurred on five flights, involving 29 secondary cases (24 cases on one flight). In addition, a further 40 flights were identified on which one or more probable cases (ie symptomatic at the time of travel) travelled but where no secondary cases developed.[70] These incidents must also be viewed in the context of the thousands of flights that took place to and from WHO defined 'affected areas' during the outbreak.

One way to reduce the risk of disease transmission would be to prevent passengers suffering from transmissible diseases from travelling. International health regulations impose a duty on airlines not to knowingly carry a passenger suffering from a range of contagious diseases and to report any suspected cases to the public health authorities. However, many cases will occur among individuals who are incubating an illness and are asymptomatic at the time of travel. In addition, the motivation to travel may be such that the individual, who feels well enough to travel, will ignore the potential to pass the illness to others.[9]

Food borne illness

There have been a number of reports of outbreaks of food borne diseases on aircraft, including cholera, shigellosis, salmonella and staphylococcal toxin poisoning.[71-79] However, when compared to the many millions of meals served on aircraft each year, the number of incidents is remarkably small and is a reflection of the high standards of hygiene associated with airline catering.

This is in contrast to the high proportion of tourists reported to experience traveller's diarrhoea and other gastrointestinal upset in relation to their holiday. Diarrhoea and vomiting are among the more frequent medical incidents that occur on board and, although passengers frequently associate such incidents with airline catering, it is probable that most are related to exposure prior to travel.

Statistics documenting incidence of food poisoning are difficult to collate, as by the time those concerned have developed symptoms, they have dispersed,[80] or the food poisoning is attributed to food eaten while abroad.

Disinsection

Aircraft disinsection is a process required by certain countries in order to reduce the risk of importation of disease spread by insect vectors. WHO has issued recommendations on the procedures and insecticides to be used, but the requirement on when disinsection must be carried out is determined by national legislative requirements. In England and Wales, the authority to require this is given in the Public Health (Aircraft) Regulations 1979 and the Association of Port Health Authorities publishes a list of originating countries where disinsection of arriving flights is required/advised.[80a]

The most frequently used justification for the requirement to use disinsection are reports of 'airport malaria' – cases of malaria occurring in individuals who work at or live in the vicinity of airports (or, in one case, a shipping port), but with no other exposure to the disease.[80b-g] Recent reviews note that 89 cases of airport malaria had been reported since 1969 and the importance of considering the diagnosis has been emphasised repeatedly.[80h-j]

In one review, the inadvertent importation of live mosquitoes is described as a "serious problem", with an "important on-going need for the disinsection of aircraft coming from airports in tropical disease endemic areas into non-endemic areas".[80j] A number of reports call for additional or more rigorous implementation of disinsection procedures.[80c, 80e, 80k]

WHO advice states that there is no evidence that the pyrethroid insecticides used are toxic to humans. However, there have been a number of anecdotal reports of symptoms such as rash, exacerbation of asthma and other allergies. Furthermore, the USA has not required disinsection of arriving aircraft since 1979 and in 1996 the US Environmental Protection Agency determined that it was doubtful that the benefits of disinsection outweighed the risks of their use.[81, 82]

Summary: Communicable diseases

- The available evidence indicates that transmission of airborne disease on board aircraft is uncommon and, when it does occur, is usually a consequence of the potential for contact and droplet spread resulting from the close proximity of passengers.
- The incidence of food borne disease on an aircraft is remarkably low.
- Aircraft disinsection is a process required by certain countries to reduce the risk of importation of disease spread by insect vectors.
- There is no robust evidence that disinsection is effective in reducing the incidence of vector borne disease, or that the pyrethroid insecticides used for disinsection are toxic to humans.

Travel fatigue and jetlag

Air travel allows individuals to travel anywhere in the world, at any time. For the long distance traveller particularly, this may lead to long days, disrupted sleep patterns and, where the journey involves trans-meridian travel (travel that crosses time zones), circadian rhythm disruption. On top of this must be added the impact of the journey itself, including travel to the airport, transit through check-in, security, gate and disembarkation procedures and further travel at the destination. It is therefore not surprising that travellers become fatigued.

Fatigue is a subjective experience and includes both physical discomfort and tiredness (such as that from cramped muscles) and mental tiredness, causing psychological and performance effects such as poor concentration, lack of energy and drowsiness. The basic remedy for fatigue is rest.

Jetlag describes a cluster of physiological and psychological symptoms that occur after trans-meridian flights and leads to the body's internal clock, and the circadian rhythms it regulates, becoming unsynchronised with the local time. Disruption of the normal circadian pattern is associated with a range of symptoms and effects, such as daytime sleepiness, difficulty sleeping in the local night, gastro-intestinal disturbance, reduced attention span and general malaise.[83] Jetlag only resolves after adaptation to the new local time.

The rate of adaptation to time zone transitions is dependent on a number of factors, including the number of time zones crossed, flight direction and age. It has been shown that, in the absence of external cues, the intrinsic periodicity of the internal 'clock' is slightly longer than 24 hours.[84] There is considerable individual variation in both the severity of jetlag and in the length of time taken to re-adjust fully. In addition, the various body rhythms adjust at different rates and therefore individuals may experience a continuing lack of wellbeing despite having apparently re-adjusted to the change. Most studies show that the majority of people find it easier to adjust to westward travel.[83, j]

While to some extent travel fatigue and jetlag are inevitable consequences of travel, there are a range of options that can be used to mitigate or counter their effects:

a) **Pre-planning.** One of the most important steps is to avoid starting the trip in a fatigued state, by ensuring adequate sleep prior to the trip. For short trips of less than three or four days it may be better to remain on home time, timing activities while away to occur as near as possible to the appropriate times in relation to the time at home. The aim is to avoid the problems of jetlag by avoiding disruption of the normal cycle, but this is difficult to sustain for a prolonged period.

j Travelling westward lengthens the day, which can be tolerated more easily due to the internal clock being slightly longer than 24 hours.

b) **Fatigue counter-measures.** The aim of fatigue counter-measures is to both minimise the effects of jetlag and facilitate adaptation to the local time. A wide range of measures has been recommended in various sources, although not all are evidence based:

i) **Sleep management.** The aim should be to obtain the same amount of sleep in any 24-hour period as normal, although not necessarily in the same pattern. A period of 'anchor sleep' – a minimum of four hours – is thought to be necessary to permit stabilisation of circadian rhythms. Additional sleep can be obtained in the form of naps, particularly timed at around the normal periods of maximum sleepiness (0300-0500 and 1500-1700[k]). 'Sleep inertia' describes the feeling of malaise that many people feel when woken from the deeper stages of sleep and can last for up to 30 minutes. Where it is important to avoid this, eg prior to a business meeting, naps should be limited to 45 minutes or less.

ii) **Sleep hygiene.** It is important to create the right environment for sleep. The sleeping environment should ideally be quiet and dark, and the use of eyeshades and earplugs may be helpful/necessary. Where there is a steady background noise, such as on an aircraft, active noise reduction headphones may be useful. These cancel out noise in the earphones using a form of electronic interference and are more expensive than simple noise attenuating earphones or earplugs. Caffeine, nicotine, alcohol and exercise can all inhibit or disrupt sleep and should be limited or avoided in the period prior to sleep.

iii) **Use of hypnotics.** The use of rapid onset, short-acting hypnotics to facilitate sleep is well established in both military and civil aviation.[85] They should only be used under the guidance of a doctor and for very short periods, to avoid the risks of dependency. Use by passengers during flight may be contra-indicated, as there is some concern that drug-induced sleep may lead to greater immobility and an increased risk of DVT.

iv) **Caffeine.** Caffeine is probably the most widely used stimulant and can be used during adaptation to help counter the periods of increased sleepiness of circadian lows. Caffeine taken orally, eg as a cup of coffee, will start to have an effect in about 15-20 minutes and its effects typically last for four to five hours.

v) **Other stimulants.** There has been recent interest in the use of stimulants, such as Dexedrine, in maintaining alertness in sustained military operations. There is evidence that they are effective, but their use requires close supervision and they are no substitute for adequate rest management and restful sleep.[86]

vi) **Melatonin.** Melatonin is a naturally occurring hormone, known to have acute and delayed effects on sleep and circadian rhythms. When correctly timed, melatonin has been shown to induce both delay and advance in circadian phase. However, if incorrectly timed, it may have adverse effects on adaptation. Short-term studies have shown few adverse effects, but there are no long-term safety data.[87] There is uncertainty about the appropriate dose that should be used and, while some studies have apparently shown clear benefit using standardised dosages, others have indicated a need for personalised dosage or no benefit at all.[88-91]

k These times initially relate to home time, although this will change towards local time as adaptation takes place.

vii) **Bright light.** The use of bright indoor light (3,000 to 10,000 lux) or daylight to re-set the circadian rhythms seems valid, in that the light/dark cycle is the most important environmental trigger. However, the timing of such exposure has to be carefully managed in relation to the circadian low (as measured by body temperature), depending on whether the aim is to advance or delay the cycle. Exposure to light after the low point will advance the circadian rhythm, as required for adaptation to eastward travel, whereas exposure before the low point will delay the rhythm, as required for westward travel.[92]

viii) **Exercise.** Exercise may have positive and adverse effects on both sleep and adaptation. As well as benefiting overall health, regular exercise is associated with a tendency to fall asleep more quickly and to sleep more soundly. However, if exercise occurs shortly before planned sleep, it may delay sleep onset. For those who exercise regularly, altering the timing of exercise can act as a trigger to help shift the circadian rhythm and therefore facilitate adaptation.

ix) **Diet.** A number of special diets have been advocated as being beneficial in assisting adaptation of circadian rhythms. However, there is no scientific evidence to support the efficacy of dietary manipulation.

Summary: Fatigue and jetlag

The basic remedy for fatigue is rest, and jetlag only resolves after adaptation to the new local time. However, there are a range of options that can be used to mitigate or counter these effects, for example, sleep management and exercise.

In-flight management of medical conditions

ICAO requirements include those for training in first aid and for carriage of medical equipment, although airlines are not expected to train cabin attendants to a level of expertise appropriate for healthcare professionals.

For example in the USA, Federal Aviation Regulation (FAR) Part 121.801 states that:

"Nothing in this subpart is intended to require certificate holders or its agents to provide emergency medical care or to establish a standard of care for the provision of emergency medical care." [92a]

However, the FAA does require operators to provide minimum specified medical equipment, including medication, on all aircraft with at least one flight attendant and, additionally, automated external defibrillators (AEDs) on all aircraft with at least one flight attendant and payload capacity greater than 7500 pounds. Further, flight attendants must be trained in emergency medical procedures, including cardiopulmonary resuscitation and the use of AEDs. Such training should be to an appropriate level, as indicated in FAR Part 121.805: "The crewmember instruction, performance drills, and recurrent training required under this section are not required to be equivalent to the expert level of proficiency attained by professional emergency medical personnel". [92a]

Medical training

The JAA regulations require cabin crew to be trained in first aid, the use of the first aid kits and to be familiar with the content of the emergency medical kit. The first aid training includes aspects of altitude physiology, including hypoxia.

Although airline training programmes have to be approved by the relevant authority, there are few requirements or guidelines on the standards that have to be achieved, either in the training programmes themselves or for the crew completing the courses. The training may be provided internally or by an external provider. However, the approving authority will request that the provider of first aid training is familiar with the aircraft environment.

Medical equipment

The standards of medical kits equipment carried on commercial aircraft vary widely, even for those airlines operating under JAA requirements.

The JAA requirements, for example, specify a requirement for first aid kits to be carried on all aircraft, with the number determined by the number of passenger seats. However, the contents specified for these kits is quite basic and there is only a requirement to carry an 'extended' medical kit on aircraft with more than 30 passenger seats and where the aircraft will, at some point in its journey, be more than 60 minutes flying time from an aerodrome at which qualified medical assistance could be expected to be available. An extended medical kit will contain a range of items including, for example, injectable drugs for use by doctors or other healthcare professionals. In addition, the specified minimum contents lists for both types of kit are given as 'Acceptable Means of Compliance' (AMC) and are therefore not mandatory. Some authorities

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l In Europe, the regulatory requirements are contained in JAR OPS 1 Sub-parts K (Instruments and Equipment) and O (Cabin Crew).

take these as their regulatory minimum, while others allow flexibility. There is no JAA requirement for carriage of automated external defibrillators (AEDs) although, in practice, most of the major airlines – and many smaller airlines – have chosen to put these on board and train crew in their use.

The Air Transport Medicine Committee of AsMA first published recommendations for aircraft medical kits in 1998 and these were updated in 2000.[93] Some airlines also publish details of their medical kits and equipment on their websites.

The BMA believes that in determining its requirements for medical kits and equipment, including automatic external defibrillators, an airline should carry out a risk assessment, taking into account factors such as the nature of its operations, duration of flights, passenger numbers and demographics, and previous medical incident records. The aviation industry regulators should produce guidelines on the standard of medical training required by crew members.

Ground to air medical support

Most major airlines have a medical department and many have provided support for crew managing in-flight medical incidents through radio and telephone links. In recent years, a number of specialist providers have offered a more comprehensive, readily accessible and 24-hour services. Typically these are based in the emergency departments of major trauma units and employ personnel with experience in remote medical management. They also have access to databases of information about emergency medical services and hospital facilities at airports around the world. They are therefore able to assist in the decisions on when and where to divert and make any necessary arrangements on the ground, as well as to assist in the management of the incident in the air.

Medical incidents

Estimates of the frequency of medical incidents vary, with two US studies in the 1980s reporting frequencies of one per 33,600 passengers and one per 39,600 passengers respectively. Evidence to the House of Lords enquiry from two UK airlines indicated frequencies of one per 12,000 and one per 1,400 passengers respectively.[9,94] It is likely that the differences reflect variations in reporting, particularly of minor symptoms such as headache, rather than true differences in the frequency of events.

A study of passengers arriving at Los Angeles International Airport, reported in 1989, examined reports from the airport first aid station, paramedic and hospital emergency department records.[95] They found 260 passengers (0.003% of the 8,735,000 passenger arrivals) who had developed symptoms in flight, of whom only 137 required assessment at an emergency department and 25 were admitted to hospital. In addition, seven passengers died during the flight.

The emergence of ground-to-air medical assistance providers has provided a further source of consistent and accurate data. Although these services do not handle the minor events that cabin crew are able to deal with on their own, they will be involved in the more significant incidents, particularly those where follow-up assessment on the ground is required.

A study published in 2000 reported 1,132 in-flight medical incidents on board a group of US airlines, all subscribing to one such medical assistance provider (the five airlines involved carried approximately 1.4 million passengers during the period of the study).[96] The data showed that the most commonly reported incidents were vasovagal episodes (22% of the total), with cardiac, neurological and respiratory symptoms being the most common potentially serious complaints. Only 179 passengers required further hospital assessment, with 173 being admitted and with an average stay of 2.8 days. The incident resulted in a diversion in 145 cases, or one per one million passengers, with almost half (45.5%) being related to cardiac symptoms. Most studies of in-flight medical incidents have identified similar patterns of incidents and diversions.[94]

The BMA recommends that airlines should collect and analyse data concerning in-flight medical incidents. They should participate, through their representative organisations, in the development of on-board medical equipment and the training of cabin crew.

Assisting healthcare professionals

Many doctors and other healthcare professionals have had the experience of volunteering to assist during in-flight medical emergencies. However, there is evidence from airline data that there is an increasing reluctance to do so, with a steady fall in the percentage of occasions when a healthcare professional responds to a crew announcement seeking a volunteer.[97]

In the UK, the General Medical Council (GMC) has stated that doctors have an ethical duty to assist in an emergency: 'In an emergency, wherever it may arise, you must offer anyone at risk the assistance you could reasonably be expected to provide.'[98] In some countries, such as France and Germany, there is a legal duty that requires a doctor to help in a medical emergency, although this does not apply to doctors of other nationalities.

The GMC also advises that doctors 'recognise and work within the limits of your professional competence' and this advice is equally applicable in the air. It is possible, with the appropriate skills, to perform complex and potentially lifesaving procedures on an aircraft, but usually the doctor's role is to assess, diagnose and advise the crew whether the situation can be managed on board or if a diversion is necessary.[14] The captain has legal responsibility for the safety of the aircraft and its passengers and the final decision on if, when and where to divert will remain in their hands. For doctors not specialised in emergency care, there may be a difficult decision about whether to intervene at all in emergencies for which they are ill equipped. Doctors should not exceed their competence unless the harm resulting from not interfering will be so much greater than the doctor at least attempting a difficult procedure.[99]

The GMC places an onus on doctors to provide emergency help, if this is reasonable. What is reasonable varies from case to case, depending on the circumstances. For example, a doctor who had consumed alcohol during the flight would have to decide whether their capability was impaired. In such circumstances, if the doctor felt that they were fit to assist, they should advise the cabin crew (and the casualty, if possible) that they have consumed some alcohol but are willing to assist if required. There are no specific guidelines from the GMC with regard to the responsibilities of doctors should a medical incident occur during a flight,but there is no ethical difference between assistance at a medical emergency on an aircraft and assistance at a medical emergency occurring anywhere else.[100]

Cabin crew may ask doctors who volunteer to assist on board for professional identification. Few doctors will have their GMC or other licence, but helpful documents may include a business card, hospital identification card, medical indemnity organisation card or membership card of a professional association such as the BMA or Royal Society of Medicine.

In any situation on board, it is the crew, and ultimately the captain, who remain legally responsible for the care of the casualty. If they have any doubt about the competence of the volunteer, they may simply ask them to resume their seat, discuss the case with a ground medical advisory service or ask the 'doctor' to talk directly to the physician on the ground. If they have serious concerns that the individual is a bogus doctor, they may also alert the authorities on the ground, who would be able to investigate further. In practice, it is exceedingly rare for bogus 'health professionals' to be encountered in relation to in-flight medical incidents.

One issue that concerns many healthcare professionals is that of legal liability for the passenger/patient's care and the outcome. From an insurance point of view, the Medical Defence Union, the Medical Protection Society and the Medical and Dental Defence Union of Scotland have confirmed that members are insured for all 'Good Samaritan' acts in an emergency where they are a bystander, anywhere in the world, including the USA and Canada. Furthermore, many airlines provide indemnity for volunteering healthcare professionals and it may be prudent to check whether this is the case on the day. In addition, if one of the ground to air medical assistance providers is involved, they may also assume the legal liability, provided their advice is followed. In some instances, it may be possible for the on-board doctor to discuss the case with the doctor on the ground, with benefit to all (although recent security restrictions on access to the cockpit may now prevent this if there are no direct communication facilities from the cabin).

However, perhaps the greatest reassurance to volunteers is the existence of 'Good Samaritan' legislation in some countries and, in particular, the US Aviation Medical Assistance Act of 1998.[101] At the moment, there is no equivalent existing or proposed legislation in the UK.

The BMA recommends that the government should facilitate a coordinated, global approach to the legal and ethical responsibilities of doctors, should they volunteer to assist at a medical incident during a flight. Consideration should be given to the identification of doctors who are called to assist in-flight medical incidents.

The BMA's general advice is that doctors should be willing to identify themselves and offer help in the event of a medical emergency during a flight. For further information please refer to the emergency care section of the BMA's handbook of ethics and law, *Medical ethics today* (2004).

Summary: In-flight management of medical conditions

- ICAO requirements include those for training of cabin crew in first aid and for carriage of medical equipment.
- Although airline training programmes have to be approved by the relevant authority, there are few requirements or guidelines on the standards that have to be achieved, either in the training programmes themselves or for the crew completing the courses.
- Standards of first aid kits and emergency medical kits are subject to regulatory requirements, although some airlines have more extensive emergency medical kits.
- Estimates of the frequency of medical incidents vary due to differences in reporting.

Conclusion

There are a number of factors that need to be borne in mind when deciding to fly. Many passengers will be contemplating their destination rather than considering the health implications of their flight. Flying is very safe for the majority of travellers, but those who are concerned should consult their doctor. When consulted, healthcare professionals have a duty to make patients aware that their condition may affect their ability to fly, or may require them to take additional precautions and/or medication. Healthcare professionals should provide patients, where possible, with evidence based information and advice. Where this evidence is lacking they must provide patients with objective information on which they can base their own decisions.

The BMA welcomes the establishment of the Aviation Health Unit, which should monitor the needs for future research and assist in coordinating such research as necessary. The government should continue to monitor current research projects concerning passenger health issues, especially those pertaining to the risk of developing a DVT (for example, the WRIGHT project) and cabin air quality (for example, CabinAir project). When further information is available the government should ensure that this is promulgated and that advice for healthcare professionals and passengers regarding fitness to travel is updated and disseminated accordingly.

The BMA believes that a great deal of research is still required to assess the impact and extent of certain factors on the health of passengers and crew. Prevention of conditions associated with flying requires effective evidence based advice and good communication between travellers and their healthcare advisers. Where robust evidence is unavailable advice should be issued on a precautionary basis.

Appendix I: International and UK authorities

International Civil Aviation Organisation

The ICAO is a specialised agency of the United Nations (as is the WHO).[6] Based in Montreal, Canada, its role is to ensure the safety, security, efficiency and regularity of air transport and it serves as the medium for cooperation between countries in civil aviation throughout the world. Almost all states (188) have joined ICAO, thereby agreeing to apply, by means of national legislation, a set of minimum regulatory standards to meet its aims. Aircraft registered in states that do not agree to comply with the minimum ICAO standards can, by international law, be refused entry into the airspace of another country, so there is a major incentive to comply with such standards. ICAO sets only minimum requirements – countries are at liberty to impose more stringent requirements if they so wish, and many do.

ICAO can occasionally facilitate changes to international practice by means of a voluntary agreement, such as its call in 1994 for member states to ban smoking on aircraft. This probably speeded the introduction of the largely smoke-free environment currently found on board airliners.

Readers will note that ICAO does not include in its role any reference to health issues. For this reason, while governments have prioritised safety (and other ICAO requirements) little attention has been given to health and flying. The House of Lords Select Committee in its report on air travel and health accepted that safety had to be paramount but continued: 'Our concern is not that health is secondary to safety but that it has been woefully neglected.' ICAO is currently (2004) considering if its role can, still remaining in accord with the international convention on civil aviation, be expanded to include health issues.

Joint Aviation Authorities

The JAA is an associated body of the European Civil Aviation Conference (ECAC) representing the civil aviation regulatory authorities of a number of European states who have agreed to cooperate in developing and implementing common safety regulatory standards and procedures. This cooperation is intended to provide high and consistent standards of safety and a 'level playing-field' for competition in Europe.[102]

European Aviation Safety Agency (EASA)

The EASA is currently being set up to:

- draw-up common standards to ensure the highest level of safety
- oversee their uniform application across Europe and
- promote them at world level.[103]

Civil Aviation Authority

The CAA is the United Kingdom's aviation regulatory authority.[104] Set up by Act of Parliament, it is responsible for ensuring that flight safety is achieved and that the UK's international responsibilities under ICAO and the JAA are met. Its work in the area of safety is undertaken by the Safety Regulation Group, which is based at Gatwick, West Sussex. Although it has a medical division, its main medically related role is to assess pilots and air traffic controllers for fitness to fly or control, given that incapacitation in these groups while working is a flight safety risk. However, a new unit called the Aviation Health Unit, has recently been set up within the division. This has responsibility for advising government through the Aviation Health Working Group on passenger and crew health issues.[105]

Aviation Health Working Group

Following publication of the House of Lords report on Air Travel and Health, the UK government recognised the need for improved oversight of aviation health related issues and set up the AHWG.[106] Chaired by the Department of the Environment, Transport and the Regions (now the Department for Transport, DfT) it brought together, for the first time in the UK, representatives from the relevant authorities: the Civil Aviation Authority, Health and Safety Executive and the Department of Health, as well as other interested parties representing the airlines, passengers, pilots and cabin crew, to consider and take forward the 47 recommendations from the House of Lords Select Committee report. One of the main decisions of the AHWG was to establish the Aviation Health Unit.

Aviation Health Unit

The Aviation Health Unit (AHU) was established on 1 December 2003, after consultation by the DfT with interested parties as to how aviation health should be addressed in the future.[105] Based within the CAA's medical division at Gatwick Airport the AHU advises the DfT on passenger and crew health issues through the AHWG. It is the first unit of its type to be set up by any government. To separate the CAA's traditional role (protecting flight safety) from that of health, the head of the unit reports directly to the DfT via the AHWG, rather than to the chief medical officer of the CAA. Further, the DfT, rather than the CAA, will impose any change to regulatory requirements advised by the AHU.

The unit will become a centre of expertise on aviation health related issues, will facilitate research in relevant topics (it does not have its own research budget) and will provide a resource to the government when questions on aviation health arise. Because the health risks associated with flying cannot be easily separated from other risks associated with travel, and because the subject is multidisciplinary, close liaison will be required between the Department of Health, the airlines and aircraft manufacturers.

World Health Organisation

Like the ICAO, WHO is a specialised agency of the United Nations.[107] One of its aims is to limit the spread of disease. Its role includes providing guidance to governments and the airline industry on the requirements for disinsection and it worked closely with the airlines, through IATA, in advising on appropriate measures to be taken in control of the SARS outbreak in 2003.

Appendix II: Cosmic radiation

The measurement of cosmic radiation and calculation of dose is not easy, because instruments tend not to measure all the different types of radiation, and each can have a different biological effect. Further, different tissues in the body can be affected to a greater or lesser extent by the same dose and type of radiation. Although it is believed that low dose exposure to cosmic radiation may be harmful in proportion to the dose (mainly increased incidence of cancer) such an assumption is theoretical, since no experimental or epidemiological evidence yet exists to demonstrate a harmful effect.[36]

Comparisons of exposure to cosmic radiation with exposure to other sources of radiation, such as chest X-rays, are frequently made. It should, however, be noted that the mechanism and extent of harm produced by a short exposure, such as an X-ray, might be very different from the same dose accumulated over several hours.

The unit of so-called 'effective' radiation dose is the Sievert (Sv) which takes into account the damaging effect of radiation to the tissues of the body. The exposure of aircrew is measured in terms of millisieverts (mSv) per year. Average ground level background radiation in the UK is 2.2 mSv per year. Investigations of cosmic radiation exposure, using both experimental data and computer modelling, have shown that aircrew typically receive an additional annual occupational exposure of 2-4 mSv and even crew operating ultra-longhaul routes over Northern latitudes were unlikely to exceed 6 mSv per year.[108-111]

In 1991, the International Commission on Radiological Protection recommended that the exposure to cosmic radiation of flight and cabin crew should be considered an occupational exposure. The occupational exposure limit for ionising radiation is 20 mSv per year and there is a requirement for additional individual assessment for those whose exposure exceeds 6 mSv per year (the 6 mSv level is an arbitrary level, with no biological significance). In 1996, the Council of the European Union issued a directive, EURATOM 1996, which included a requirement for appropriate measures to be taken for aircrew who are liable to exposures of more than 1 mSv per year. These include the assessment of the level of exposure, changes to work schedules where necessary, provision of information to crews and additional measures for female crew during declared pregnancy.[112]

It can be calculated that an airline pilot or cabin crew member exposed to an occupational exposure is 3 mSv per year for 45 years has an increased risk of dying from a cancer induced by his exposure to cosmic radiation is about 0.45 per cent.[113] This must be added to the general population risk of death from cancer of 23 per cent, so the added risk is small (and theoretical).

There have been a number of studies of mortality and cancer incidence among flight crew and cabin crew, with several recent and ongoing studies under the auspices of the European Community.[114] Overall, these studies suggest increased risk for malignant melanoma, non-melanoma skin cancer and, possibly, acute myeloid leukaemia among flight crew and of malignant melanoma and breast cancer for cabin crew. However, it is unclear whether these observed excesses are due to occupational exposure or non-occupational factors, such as reproductive history or lifestyle.[115,116]

There is a small increased risk of genetic defects in the offspring of men or women exposed to increased levels of cosmic radiation during a flying career. This has been estimated as an added risk of 1 in 1,000 (after 20 years flying) compared with the rate in the general population of 1 in

50. In any individual case of a genetic defect it is therefore likely that the defect is due to some factor other than exposure to cosmic radiation.[117]

There is also a risk to the foetus of a pregnant crew member. During the first day after conception the foetus is particularly radiosensitive but thereafter becomes less so. As with the potential for causing genetic abnormalities, it is not possible to separate the early effect of cosmic radiation on the foetus from other harmful influences, since, even in the absence of cosmic radiation, a large number of pregnancies result in early foetal death. Nevertheless, the European Union Directive limits the occupational exposure of a pregnant aircrew member to 1 mSv during the remainder of pregnancy following its declaration to the employer.[118] In adhering to the principle of keeping doses 'as low as reasonably achievable', the so-called ALARA principle, many employers choose to ground pregnant aircrew once pregnancy is declared.

Appendix III: Aircraft seating

Seat pitch is the distance from a fixed point on one seat to the same point on a seat in the next row. It does not take into account factors such as the depth of the seat cushion and backrest, available space under the seat in front, width of the seat or the impact of reclining the backrest and, therefore, gives only limited information on the space available to the seat occupant.

Regulations with regard to aircraft seating are solely concerned with issues of safety, and in particular the protection of the occupants in the event of sudden accelerations and decelerations, such as those that may occur in turbulence, take-off and landing and in the event of an accident. Few countries have any regulations on minimum seat dimensions, although these are specified by the UK CAA in its Airworthiness Notice AN 64. These dimensions were specified in relation to work carried out on the requirements to allow safe evacuation of an aircraft within a specified time period and are not based on any issues of health or comfort.

In 2000, the JAA commissioned a review of aircraft seating dimensions by 'ICE Ergonomics', which might form the basis for possible JAA regulation in this area. The study considered anthropomorphic data, including considerations of change over time, a passenger survey, expert opinion and computer modelling analysis. The report also considered health issues, although this was confined to a review of the literature on DVT.

The report made a number of recommendations, including proposals for increases in the minimum dimensions specified in AN 64, specifications for a 'foot clearance envelope', width and depth of the seat base and for armrests. The report also concluded that the contribution of seat design and spacing to the development of thrombo-embolic disease is not known. Further work was required to validate the recommendations and to investigate any relationship between seating parameters and thrombo-embolic disease.[119]

To date, no further research has been carried out or commissioned to validate the recommendations on seat specifications and no JAA regulations have been proposed.

Appendix IV: Aircraft cabin environment

The environment inside a commercial aircraft is managed by the ECS. The system must provide comfortable surroundings for both the relatively inactive passengers and for the cabin crew, who may at times be carrying out moderately strenuous physical work.

It therefore has to control the pressure within the cabin, provide adequate ventilation to ensure an adequate supply of oxygen, remove carbon dioxide and other contaminants and odours, and provide a comfortable temperature.

Regulatory aspects

In designing an aircraft environmental control system, the manufacturer has to comply with certain regulatory requirements. In Europe, the regulations are laid down by the JAA in the Joint Aviation Requirements JAR-25.[120] They were developed such that they largely mirror the requirements of the FAA, contained in Federal Air Regulations Part 25, in the United States.[121] The aircraft operators are required to operate the aircraft in accordance with the manufacturer's specifications, to ensure that the regulatory requirements are achieved.

The regulations lay down specific requirements in some areas, such as minimum cabin air pressure, maximum levels of carbon monoxide, carbon dioxide and ozone, and minimum ventilation flow rates. There is also a general requirement that the crew and passenger compartment air must be free from harmful or hazardous concentrations of gases or vapours (JAR 25.831). Recently, work has been carried out in the European CabinAir project, part of the European Commission's 5th Framework research programme, and also by a committee set up by the American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc. (ASHRAE), to examine cabin air quality and to try and develop a more comprehensive set of standards appropriate to the environment.[122] The results of the CabinAir project are likely to be available soon, but there is currently no fixed end-point for the work of the ASHRAE committee.

How an aircraft environmental control system works

Outside air enters the aircraft engines and some of the air, 'bleed air' is drawn off at the low compression stage, prior to combustion. The compressed air is at high temperature and initially passes through air-conditioning packs and ozone converters (where fitted). On most modern aircraft, the air is then mixed with filtered, recirculated air, before being distributed to the cockpit and passenger cabin. The systems are designed to provide approximately 20 cubic feet (566 litres) of air per minute per passenger, of which about half is recirculated air (compared with up to 80% re-circulated in many buildings), giving a complete cabin air exchange of air every two to three minutes.

The high ventilatory flow rates are necessary to maintain overall temperature control, remove odours and carbon dioxide, and to maintain normal pressurisation. The system must also supply oxygen, but the high ventilation rates mean that the amount of oxygen supplied far exceeds that required by the occupants of approximately 0.34 l/min when sitting and 0.85 l/min when walking.[13]

However, because of the large mass of air entering the relatively small volume of the cabin, the distribution must be carefully controlled to ensure adequate mixing of the air in the cabin and to prevent draughts. The air enters the cabin through overhead distribution outlets, which run the length of the cabin. The design of the outlets creates a controlled circular pattern of airflow, and the air is continuously extracted through vents at floor level. The airflow is around, rather than along the cabin, and this minimises the potential for spreading passenger-generated contaminants.[123]

All current commercial aircraft that use recirculation systems utilise filtration to ensure that contaminants, such as infective particles, are removed from recirculated air. The filters found in most[m] modern aircraft are High Efficiency Particulate Air (HEPA) filters, of the type used in hospital intensive care units and operating theatres, and offer up to 99.99 per cent efficiency.

Concern has been expressed that the use of recirculated air leads to a lower quality of air than in systems using 100 per cent outside air.[9] Scientific evaluations of cabin air quality have been carried out by a number of authorities, including the National Research Council, US Department of Transportation, National Institute for Occupational Safety & Health, ASHRAE and BRE.[122,124-126] All such studies have shown that these systems meet the regulatory standards, eg for ventilatory flows, carbon monoxide and carbon dioxide, as well as achieving levels of volatile organic compounds, microbes, and allergens within the requirements for indoor air quality standards for offices and homes.

The National Research Council report did highlight the lack of information on the nature, severity, frequency and potential health effects of incidents in which systems malfunction, allowing contaminants to enter the cabin.[124] This issue was also noted in the House of Lords Science & Technology Committee report.[9] However, investigation of such unpredictable and infrequent events is extremely difficult and, to date, there is no published research that has identified any health effects of such events.

The single parameter that is consistently below that found in office or home environments is the level of relative humidity, which has been found to be around 15-20 per cent in the cruise on shorthaul aircraft and may fall as low as 5-10 per cent on longhaul aircraft. Indoor levels in the UK are typically 30-60 per cent. These levels are commonly associated with surface drying of skin, mucous membranes and cornea, and with some increase in insensible fluid losses. However, the frequently expressed view that the low humidity levels result in dehydration is incorrect, as normal homeostatic mechanisms operate to prevent this.[127]

m All UK commercial aircraft have either HEPA filters or alternative filtration systems delivering equivalent levels of efficiency.

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