CHAPTER 46 Aircraft Cabin Environment

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KEYPOINTS

- Though the occupant density, noise and vibration, and relative immobilization may cause physical and/or emotional stresses, the modern commercial aircraft cabin is maintained with adequate environmental control for the comfort of most healthy individuals
- In most cases, cabin air is a combination of both outside air and recirculated air that has gone through HEPA filtration
- Transmission aboard aircraft of illnesses, such as tuberculosis, SARS and other respiratory diseases, has been reported, but infrequently documented. There is no evidence of disease transmission via the environmental control system
- Automated defibrillators, other sophisticated equipment and telemedicine have saved lives of critically ill passengers. Nonetheless, a passenger's fitness to fly is a responsibility of both the traveler and his or her healthcare providers
- Pre-flight notification of special needs and assistance will reduce the stress of a journey and enhance the standard of service delivered by the airlines

INTRODUCTION

The physiology of the human being is optimized for existence at sea level. Most individuals, however, can ascend to around 8000–10 000 ft (2500–3000 m) above sea level before hypoxia begins to have ill effects and reduces performance.

With increasing altitude, there is a fall in the atmospheric pressure, together with a decrease in density and temperature. The pressure at sea level in the standard atmosphere is 760 mmHg and this falls to half at 18 000 ft (5500 m), where the ambient temperature is about −20°C. The composition of the atmosphere remains constant up to the tropopause (36 000 ft or 11 000 m), the most abundant gases being nitrogen (78%) and oxygen (21%), with the remaining 1% being argon, carbon dioxide, neon, hydrogen and ozone.

The relationship between the oxygen saturation of hemoglobin and oxygen tension minimizes the effect on the human of the reduction in partial pressure of oxygen. Ascent to an altitude of 10 000 ft (3000 m) produces a fall in the partial pressure of oxygen in the alveoli, but only a slight fall in the percentage saturation of hemoglobin with oxygen. Once altitude exceeds 10 000 ft (3000 m), however, the percentage saturation of hemoglobin falls quickly, resulting in hypoxia. Indeed, above 8000 ft (2500 m), the effects of lack of oxygen will begin to appear and a decrease in an individual's ability to perform complex tasks and a reduction in night vision can be measured.[1]

Figure 46.1 shows the oxygen dissociation curve of blood. The concentrations of physically dissolved and chemically combined oxygen are shown separately and the curve illustrated is the average for a fit young adult. The actual shape of the curve will be influenced by factors such as age, state of health, tobacco use and ambient temperature.

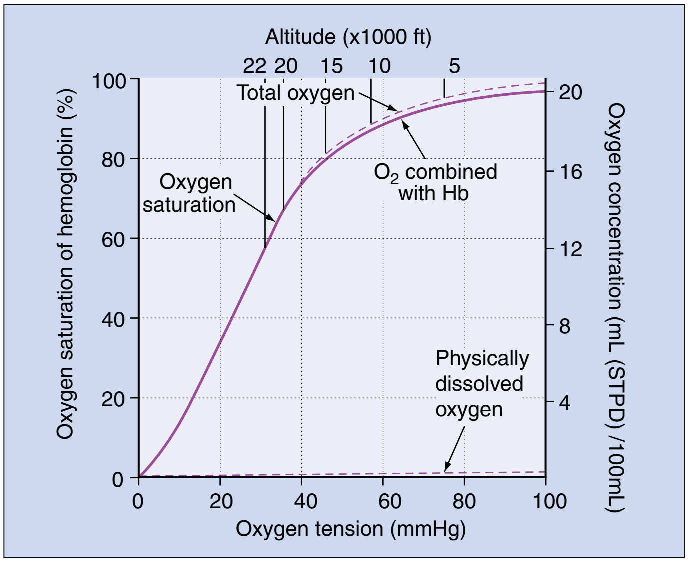

Figure 46.1: The oxygen dissociation curve of blood.

Healthy individuals can tolerate altitudes of up to 8000–10 000 ft (2500–3000 m) with no harmful effects. However, in the case of the elderly or of individuals suffering from some diseases of the respiratory or circulatory system, there is less tolerance of the mild hypoxia at even this altitude. In an ideal world, the cabin would be pressurized to maintain sea level conditions. To achieve this would require an extremely strong and heavy aircraft structure with severe implications on load carrying capacity, fuel consumption and resulting effects on the external environment. As a result, a compromise has to be struck, and airworthiness regulations (US Federal Aviation Regulations and European Joint Aviation Requirements) state that 'pressurized cabins and compartments to be occupied must be equipped to provide a cabin pressure altitude of not more than 8000 ft (2500 m) at the maximum operating altitude of the aeroplane under normal operating conditions.'[2]

THE PRESSURIZED CABIN

Pressurization is achieved by tapping bleed air from the engine compressors and passing this flow of air through the air-conditioning packs into the cabin. The outside air is very dry and cold, and the temperature is controlled via the air-conditioning packs. The cabin pressure is maintained at the desired level by regulating the flow of air overboard. Figure 46.2 illustrates ambient and cabin altitudes for a typical flight.

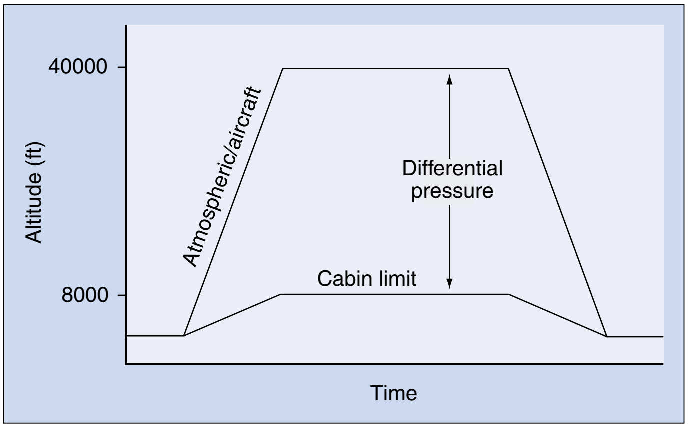

Figure 46.2: Typical cabin pressure flight profile.

Figure 46.3 shows how the air circulates in the cabin in the case of a single aisle, while Figure 46.4 shows the airflow patterns in a twin aisle cabin.

As a result of the required cabin pressure change during climb and descent, it is possible for individuals to suffer discomfort as a result of expansion of gas trapped within the body. In particular, gas can be trapped within the gut and within the middle ear and sinuses. Normally, this trapped gas is able to escape without any problem, but there may be occasions when this is not so, such as when the individual is suffering from upper respiratory tract congestion due to infection or allergy. In particular, the human ear is very sensitive to rates of pressure change, the threshold for detection being 0.132 PSI (0.910 kPa). This is equivalent to a change in cabin altitude of 250 ft (76 m) at sea level. In the human ear, the cavity of the middle ear is separated from the outer ear by the tympanic membrane. It communicates with the nasopharynx and, in turn, the atmosphere by way of the eustachian tube, the proximal two-thirds of which has soft walls that are normally collapsed. During ascent to altitude, the gas in the middle ear cavity expands and escapes along the eustachian tube into the nasopharynx, equalizing the pressure across the tympanic membrane. The pharyngeal portion of the eustachian tube acts as a one-way valve, thus allowing expanding air to escape easily to the atmosphere. This can be sometimes felt as a ‘popping’ sensation as air escapes from the tube during ascent.

During descent, air from the nasopharynx must enter the middle ear to maintain equilibrium. In some individuals, the one-way valve mechanism of the eustachian tube can prevent passive flow of air back into the middle ear cavity. This causes a relative increase of pressure on the outside of the tympanic membrane, pushing it into the middle ear cavity and causing a sensation of fullness, a decrease in hearing acuity and eventually pain. It is possible to perform active maneuvers to open the eustachian tube, such as swallowing, yawning, and jaw movements. In some people, these simple maneuvers are not effective and it may be necessary to occlude the nostrils and raise the pressure in the mouth and nose to force air into the middle ear cavities. This increase in pressure can usually simply be achieved by raising the floor of the mouth with the glottis shut, while other individuals raise the pressure in the lungs and the respiratory tract by contracting the expiratory muscles while forcibly exhaling (Valsalva’s maneuver).

In addition to regulating the airflow rate required to pressurize the aircraft, the environmental control system controls the flow rate of outside air required to remove contaminants and controls the temperature in the cabin. This requirement is facilitated by the practice of recirculation of approximately 50% of the cabin air. This is achieved by extracting air from the cabin and mixing it with conditioned outside air. Recirculation provides two benefits: one, it allows the total

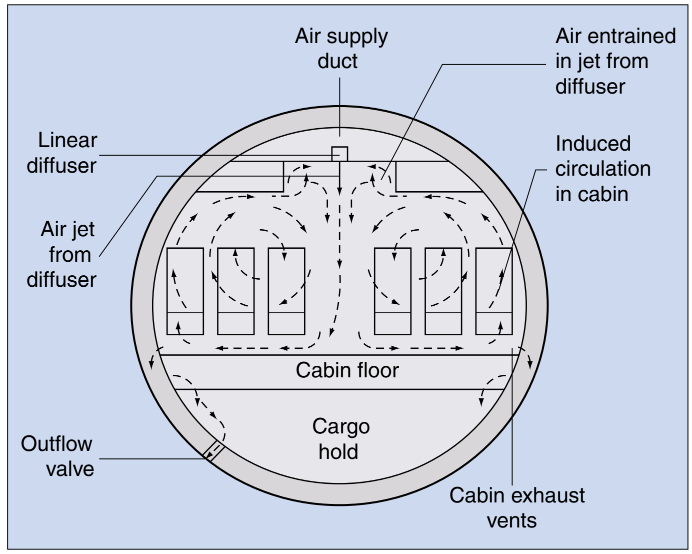

Figure 46.3: Cross-section of single-aisle aircraft with air circulation paths.

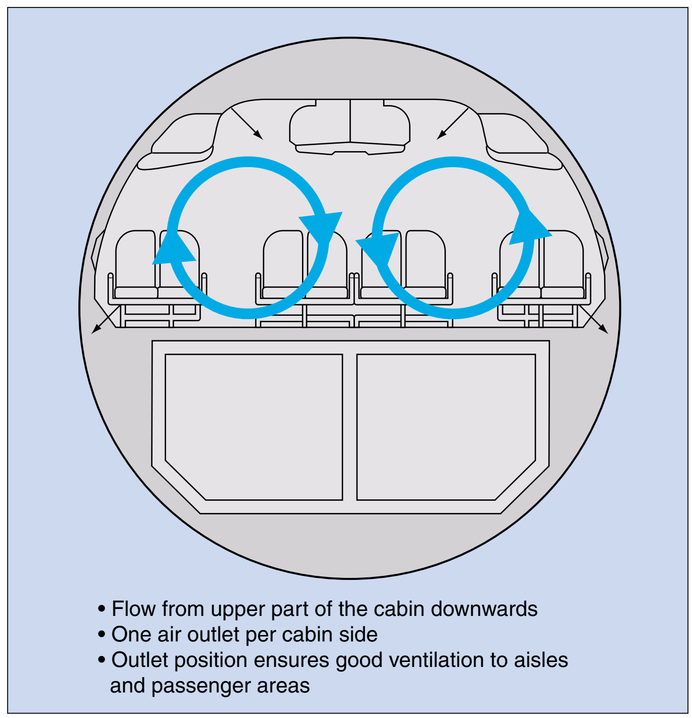

Figure 46.4: Examples of air flow patterns in the twin-aisle cabin.

airflow rate to be higher than the flow rate of the outside air, so good circulation in the cabin can be maintained independently of the outside airflow; and two, the conditioned air is mixed with comparatively warm recirculated air before being introduced into the cabin. As a result, the conditioned air is supplied at a much lower temperature without causing discomfort from cold drafts. The recirculated air will also have picked up moisture from the cabin occupants and the cabin activities, improving the humidity level. In older generation jet aircraft, all the air supplied to the cabin came from outside air, without the benefits of recirculation (improved humidity, reduction in perceived drafts). This practice was inefficient with a substantial energy, and hence environmental, cost.

In pressurized jet aircraft manufactured since the beginning of the 1980s, the recirculated air is passed through filters. These are high efficiency particulate (HEPA) filters, which have an efficiency of 99.97% for 0.3 μm particles. They are effective in removing bacteria and viruses from the recirculated air, so preventing their spread through the cabin by this route. Air filters are changed during routine aircraft maintenance, as specified by the manufacturer in the servicing schedule.

Recirculated air is obtained from the area above the cabin or under the floor; air from the cargo bay, lavatories and galleys is not recirculated. The flow rate of outside air per seat ranges from 3.6 to 7.4 L/s (7.6–15.6 cubic ft/min) with the percentage of recirculated air distributed to the passenger cabin being of the order 30–55% of the total air supply.[3] The result of filtering the recirculated air is a significant improvement in cabin air quality by the removal of particles and biological microorganisms. It is not necessary to pass the compressed air from outside through HEPA filters, because the ambient air at high altitude is free of microorganisms and particulates.

The use of recirculation has been common in the design of building environmental control systems for many years. Building environmental systems are commonly designed and operated with up to 90% of recirculated air, which compares with the maximum recirculated air flow in aircraft of 55%.

The air supply to the flight deck (or cockpit) is derived from the same source, but is delivered at a slightly higher pressure than the air supplied to the cabin. This ensures a positive pressure differential to prevent the ingress of smoke or fumes to the flight deck in the event of a fire or similar in-flight emergency. The flow rate of the flight deck air supply is also slightly higher than that to the cabin because this supply is used for cooling the avionics and other electronic equipment.

HUMIDITY

Humidity is the concentration of water vapor in the air. Relative humidity is the ratio of the actual amount of vapor in the air to the amount that would be present if the air was saturated at the same temperature, expressed as a percentage. Saturated air at high temperatures holds more water vapor than at low temperatures, and if unsaturated air is cooled, it becomes saturated. High humidity can lead to passenger and crew discomfort when it is accompanied by high temperature. High humidity can cause condensation, dripping and freezing of moisture on the inside of the aircraft shell, which may lead to safety problems such as corrosion. Condensation can also give rise to biological growth thus causing adverse effects on cabin air quality.

At a typical aircraft cruising altitude of 30 000 ft (9150 m), the outside air temperature is in the region of −40°C and is extremely dry, typically containing about 0.15 g/kg of moisture. For pressurized aircraft flying at these levels, the conditioned air entering the cabin has a relative humidity of <1%. Exhaled moisture from passengers and crew, together with moisture from galleys and toilet areas, increases the humidity to an average level of 6–10%, which is below the 20% normally accepted as comfort level.[4]

Research has shown that the maximum additional water lost from an individual during an 8-h period in 0% humidity, compared with normal day-to-day loss, is around 100 mL. The sensation of thirst experienced by healthy individuals in the low humidity environment is due to local drying of the pharyngeal membranes, and this itself may lead to the spurious sensation of thirst. There is no evidence that exposure to a low-humidity environment itself leads to dehydration, although local humidity can cause mild subjective symptoms, such as dryness of the eyes and mucous membranes.[5,6]

No significant effect has been shown on reaction time or other measures of psychomotor performance, although there can be some changes in the fluid regulatory hormones.[5,6] It is unlikely that low humidity has any long- or short-term ill-effects, provided overall hydration is maintained by drinking adequate amounts of fluid.[7] The body's homeostatic mechanisms ensure that central hydration is maintained, although the peripheral physical effects can lead to discomfort. Dry skin can be alleviated by using moisturizing aqueous creams, particularly just before flight, and dry eye irritation can be alleviated by the use of moisturizing eye drops. Individuals prone to develop dry eyes are advised not to wear contact lenses during long flights in pressurized aircraft.[8] A National Academy of Sciences report identified humidity as one of the areas deserving more attention in future research concerning aircraft cabin environment.[9]

The aircraft cabin is similar to many other indoor environments, such as homes and offices, in that people are exposed to a mixture of external and recirculated air. The cabin environment is different in many respects (e.g. the high occupant density, the inability of the occupants to leave at will and the need for pressurization). In flight, there is a combination of environmental factors including low air pressure and low humidity, as well as low frequency vibration and constant background noise. Although the noise and vibration can contribute to fatigue, the levels are all below those which are accepted as potentially harmful to hearing.[9,10]

OZONE

Ozone is a highly reactive form of oxygen found naturally in the upper atmosphere. It is formed primarily above the tropopause as a result of the action of UV light on oxygen molecules. The amount and distribution of natural ozone in the atmosphere varies with latitude, altitude, season and weather conditions. The highest concentrations in the northern hemisphere are generally found at high altitude over high latitude locations during the winter and spring.

The effects of high ozone concentration on human beings can include eye irritation, coughing due to irritation of the upper respiratory system, nose irritation and chest pains. As a result of this, the airworthiness regulatory authorities (e.g. US Federal Aviation Authority, European Joint Aviation Authorities) require that transport category aircraft operating above 18 000 ft (5500 m) must show that the concentration of ozone inside the cabin will not exceed 0.25 parts/million by volume (sea level equivalent) at any time, and a time weighted value of 0.1 parts/million by volume (sea level) for scheduled segments of >4 h.[11]

For this reason, long haul transport jet aircraft are now equipped with ozone catalytic converters that break down or 'crack' the ozone before it enters the cabin air circulation.

COSMIC RADIATION

Natural radiation consists of cosmic rays from outer space (galactic radiation) and the gamma rays from rocks, earth, and building materials. Cosmic radiation is produced when primary photons and alpha particles from outside the solar system (galactic cosmic radiation) interact with components of the earth's atmosphere. A second source of cosmic radiation is the release of charged particles from the sun, which becomes significant during periods of solar flare ('sun storm'). Cosmic radiation is an ionizing radiation; ionizing radiation also includes X-rays and that from radioactive materials. Ionizing radiation is a natural part of the environment in which we live and is present in the earth, buildings, food we eat, and even in the bones of our bodies. The other type of radiation is known as non-ionizing radiation and this includes UV light, radio waves and microwaves.

Humans, animals and plants have all evolved in an environment with a background of natural radiation and, with few exceptions, it is not a significant risk to health.

The amount of cosmic radiation that reaches the earth from the sun and outer space varies and depends on the latitude and height above sea level. The amount of cosmic radiation entering the atmosphere follows an 11-year cycle, with the intensity of galactic radiation being lowest when solar activity is at its highest. This is because during high levels of solar activity, the resulting magnetic flux between the sun and the earth deflects much of the galactic cosmic radiation. Cosmic radiation is effectively absorbed by the atmosphere and is also affected by the earth's magnetic field. The effect on the body will depend on the latitude and altitude at which the individual is flying and also on the length of time in the air.

Cosmic radiation may be measured directly using sophisticated instruments, as was done in the Concorde supersonic transport and subsonic long range aircraft, or can be estimated using a computer software program. These programs look at the route, time at each altitude and the phase of the solar cycle, and calculate the radiation dose received by the aircraft occupant for a particular flight. A number of airlines and research organizations have compared actual measurements taken on board an aircraft with the computer estimations, and the two are very similar.[12]

The effect of ionizing radiation depends not only on the dose absorbed, but also on the type and energy of the radiation and the tissues involved. These factors are taken into account in arriving at the Dose Equivalent measured in Sieverts (Sv). However, doses of cosmic radiation are so low that figures are usually quoted in microsieverts (μSv, millionths of a Sievert) or millisieverts (mSv, thousandths of a Sievert).

When ionizing radiation passes through the body, energy is transmitted to the tissues, which affects the atoms within the individual cells. Very high levels of radiation, such as that from a nuclear explosion, will cause severe cell damage in a human being, particularly to the bone marrow cells and the reproductive cells, which cannot be repaired by the body. Low-level doses of radiation, such as cosmic radiation or medical X-rays, do not cause such severe damage to the cells and in most cases, any such damage is repaired satisfactorily by the body's own mechanism. It is not possible to predict a maximum safe threshold of exposure to low levels of radiation, because individuals vary in their biological response.[8,12]

The International Commission for Radiological Protection (ICRP) recommends maximum mean body effective dose limits of 20 mSv/year (averaged over 5 years) for workers exposed to radiation as part of their occupation (including flight crew), and 1 mSv/year for the general population, with an additional recommendation that the equivalent dose to the fetus should not exceed 1 mSv during the declared term of pregnancy.

When the Concorde supersonic transport aircraft was flying, the effective dose rate for the occupants at cruising altitude was measured to be in the range of 12–15 μSv/h. On ultra long-haul flights at high latitudes, such as a Boeing 747-400 flying between London and Tokyo, the effective dose rate at cruising altitude is around 5 μSv/h. On short-haul commercial operations, the effective dose rate in Europe is in the region of 1–3 μSv/h.

For typical annual flight schedules, crew members accumulate around 4 or 5 mSv/year operations, and between 1 and 2 mSv/year on European short-haul operations from cosmic radiation.

For airline passengers, the ICRP recommended limit for the general public of 1 mSv/year equates to about 200 flying hours/year on the trans-equatorial routes. There are essentially two types of airline passenger: the occasional social traveler and the frequent business traveler. The public limit (1 mSv/year) will be of no consequence to the social traveler but could be of significance to the frequent business traveler. The 1 mSv annual limit would be exceeded if the business traveler were flying more than eight transatlantic or five antipodean return journeys per year. Business travelers are exposed as an essential part of the occupation, and it is entirely logical to apply the occupational limit of 20 mSv/year to this group.

Cosmic radiation is of no significance at altitudes below about 25 000 ft (7600 m) because of the attenuating properties of the earth's atmosphere. There is no evidence from epidemiological studies of flight crew of any increase in incidence of cancers linked to ionizing radiation exposure, such as leukemia. In general terms, as far as the risk of developing cancer induced by radiation exposure is concerned, it has been calculated that an accumulated dose of 5 mSv/year for 20 years increases the risk of developing cancer (in the general population) from 23–23.4%, i.e. an increase of risk of 0.4% over 20 years. Compared with all the other risks encountered during a working life, this is very low.

Cosmic radiation is both a complex and emotive subject. It cannot be seen, touched, smelled or tasted and yet it is present all around us. While it is known that there is no level of radiation exposure below which effects do not occur, all the evidence indicates that there is an extremely low probability of airline passengers or crew suffering any abnormality or disease as a result of exposure to cosmic radiation.

PESTICIDES IN THE CABIN

The World Health Organization and the International Civil Aviation Organization recommend that aircraft arriving through countries reporting certain indigenous infectious diseases, be treated with pesticides.[13] This remains a controversial issue. While it is understandable that countries such as New Zealand would not want to risk the entry of certain vector-borne diseases transmitted by mosquitoes, there remains concern about the safety and efficacy of various pesticides used, particularly while passengers are in the cabin (top of descent spraying). There appears to be less concern about using residual pesticides during routine aircraft maintenance. At this time, however, the US Environmental Protection Agency has not promoted the registry of any pesticides in the USA for use in aircraft disinsection on American carriers. As vector-borne diseases re-emerge, however, these policies may need re-evaluation in order to prevent the transmission of disease. Further education of air crew and passengers will be needed, and these issues are being reviewed.

AIR-BORNE DISEASE IN THE CABIN

There are five main routes by which microorganisms may be transmitted to humans: contact (direct and indirect), droplet, air-borne, common-vehicle, and vector-borne.[14] All of these modes have been implicated, at least anecdotally, in the transmission of disease aboard an aircraft;[15–18] however, there has been increasing concern over the respiratory spread of infections during air travel, via droplet and air-borne transmission. Droplet transmission may occur whenever a person coughs, sneezes, or talks.[14] Droplets are relatively large particles (>5 μm) that can travel only a short distance through the air; they do not remain suspended. Infection occurs when microorganisms within the droplets come into contact with the conjunctivae, nasal mucosa, or mouth of a susceptible person. In air-borne transmission, smaller respiratory particles (≤5 μm), called droplet nuclei, are inhaled by a susceptible host. These particles remain suspended in air indefinitely and may spread over long distances, depending on environmental factors.[14]

Humans are the most important reservoirs of infectious agents on aircraft. Most microorganisms that have been isolated from occupied spaces, including aircraft cabins, are human in source, including bacteria that have been shed from exposed skin and scalp, as well as from the nose and mouth.[9] These microorganisms are typically part of the normal human flora and very rarely cause infections. Studies have shown no statistically significant differences in the concentrations of bacteria and fungi sampled from the aircraft cabin:

- among different aircraft, airlines or flight durations
- between aircraft cabins and other types of public transport vehicles
- between aircraft cabins and typical indoor and outdoor urban environments.

When microorganisms are spread by droplet transmission, the risk of acquiring infection is highest for the passengers seated closest to a source person, typically within 3 feet.[14] In contrast, microorganisms that are spread by air-borne transmission potentially could distribute throughout the entire aircraft cabin. In reality, however, this does not occur. Microorganisms suspended in cabin air are removed by the high efficiency particulate (HEPA) filters during the air recirculation process; unfortunately, these filters provide no protection from the cough or sneeze emitted by an infected neighbor. The natural or acquired immunity of most individuals prevents the development of infectious disease.

Limited data are available on the true risk of disease transmission during air travel. Studies of potential infectious disease transmission on aircraft have considered tuberculosis, influenza, measles, meningococcal disease, SARS, and acute respiratory infections, such as the common cold.[19,20]

Tuberculosis

The transmission of *Mycobacterium tuberculosis* (TB) during air travel has been most extensively studied. TB is transmitted by the inhalation of droplet nuclei (air-borne transmission). Two of six investigations conducted by the Centers for Disease Control and Prevention (CDC) between 1992 and 1995 have indicated that the transmission of TB from a symptomatic person to other passengers or crew members does occur during air travel.[21,22] In one investigation, a flight attendant was diagnosed with cavitary pulmonary tuberculosis in November, 1992. Of the 212 flight crew who worked with this flight attendant between August and October, 1992, 25.6% had a positive tuberculin skin test (TST) result. Two of these contacts had documented conversion of TST status. TST positivity and conversion was associated with a cumulative flight-time exposure of 12 h or more. In the second investigation, a foreign-born passenger developed symptomatic pulmonary tuberculosis while visiting friends in the USA. She traveled from Baltimore, Maryland to Chicago, Illinois (2 h flight) and then from Chicago to Honolulu, Hawaii (8 h and 38 min flight). Three of the 113 passengers on the Baltimore to Chicago flight had a positive TST, two were foreign-born. Fifteen of the 257 passengers on the flight from Chicago to Honolulu had a positive TST. Four of these passengers converted their TST. In both investigations, all of the new infections were latent TB infection; none developed active tuberculosis.

The HEPA filters used in newer commercial aircraft are able to filter out TB bacteria from the recycled air and are also used in hospital respiratory isolation rooms to prevent the spread of TB within the hospital setting. The number of air exchanges per hour in aircraft exceeds the number recommended for hospital isolation rooms. Furthermore, the prevalence of transmissible tuberculosis among air travelers is estimated to be 5–100/100 000 passengers, depending on the route of the plane.[23] The risk of TB transmission on a commercial aircraft, therefore, remains low. Mathematical models estimate that the chance of acquiring TB during air travel while sitting near a highly infectious source is approximately 1 in 1000.[24]

Influenza

Human influenza virus is spread by droplet and air-borne transmission.[25] One of the first well-documented outbreaks of influenza on a commercial airline was published by Moser and colleagues in 1977.[17] Thirty-eight of 54 passengers and crew members became ill after exposure to a passenger with symptomatic influenza infection. Another two passengers showed serological evidence of infection without becoming ill. The outbreak was attributed to an engine malfunction, which required the aircraft to remain on the runway for approximately 4.5 h without adequate ventilation. Most of the passengers remained on the plane during the delay, and the clinical attack rate varied with the amount of time spent aboard the aircraft.

Another outbreak of presumed influenza that was associated with air travel occurred among workers traveling from a remote mine in northwestern Australia.[26] One worker became symptomatic with an influenza-like illness prior to the flight, which lasted 3 h and 20 min. Over the 3–4 days that followed the flight, 15 workers presented with similar complaints and were unable to work. An additional five workers reported upper respiratory tract symptoms when questioned but were able to continue working. There was no ventilation system malfunction reported for the aircraft associated with this outbreak. A significant limitation of this report is the lack of etiologic confirmation.

Since 1997, a new strain of avian influenza virus (H5N1) has been responsible for a number of outbreaks involving a large number of birds, and rarely, humans. From December 2003–February 2007, 237 laboratory-confirmed human infections were identified in Asia and SE Asia, and have primarily been due to direct contact with poultry.[25,27] Limited, non-sustained person-to-person spread has also been described in a few cases. As with SARS, the airline industry will look to public health authorities for guidance in the event that an (avian) influenza pandemic should occur.

SARS

The Severe Acute Respiratory Syndrome (SARS) was first identified in Southern China in November, 2002, and recognized as a global threat by March, 2003.[28] It was caused by a novel coronavirus, the SARS-associated coronavirus, and was spread primarily via droplet transmission, although spread by air-borne and contact transmission could not be ruled out. Despite the clear role of international travel in the spread of SARS during the 2003 outbreak,[28,29] there had been only one case of likely in-flight transmission.[30] Limited transmission probably occurred aboard aircraft, but the risk was felt to be low. Fortunately, no suspected cases of SARS have been reported since May, 2004.[31]

Meningococcal disease

Neisseria meningitidis is a leading cause of meningitis and sepsis in children and young adults and is spread by droplet transmission. Meningococcal disease has been documented in travelers, particularly those traveling for the *Hajj*; however, transmission due to exposure while aboard an aircraft has not been definitively documented.[20] Guidelines for the management of airline passengers who have been exposed to meningococcal disease are based on information available from investigations of TB transmission aboard aircraft. US guidelines are online and available at: http://www.cdc.gov/travel/menin-guidelines.htm

Measles

Measles is a highly contagious viral disease that is spread by air-borne transmission. A person infected with measles is contagious from the first onset of vague symptoms (up to 4 days before rash appears) to approximately 4 days after the development of rash; therefore the potential for disease transmission during air travel exists. From 1996 to 2000, 63 of the 207 cases of imported measles into the USA developed a rash directly before or on the day of air travel. From these imported cases, only one documented case of in-flight transmission was reported.[32] Despite the risk, few cases of measles occur as a direct result of in-flight exposure.[32,33] Amornkul and colleagues investigated the extent of measles transmission aboard an international commercial flight after exposure to an infected passenger.[32] Of the 276 potentially exposed passengers, 82% completed a follow-up questionnaire, including

29 passengers who reported close contact with the ill passenger before, during, or after the flight. None of the contacted passengers reported symptoms consistent with measles.

Available data indicate that infectious agents can be transmitted from person-to-person aboard an aircraft on the ground and during flight, just as they can in any other situation where people find themselves in close proximity. From investigations of disease outbreaks associated with air travel, two main risk factors for the spread of communicable diseases have been identified: flight duration (>8 h, including ground time) and seating proximity to the source. There is no evidence that the pressurized cabin itself makes transmission of disease any more likely. Once the aircraft doors are closed, air-conditioning is provided from the auxiliary power unit until it can be supplied from the aircraft engines, thus ensuring the filtration benefits of air recirculation. There does appear to be increased risk of disease spread when the aircraft ventilation system is inoperable.

Guidelines are in place to assist flight crew in the management of ill passengers and can be accessed from www.who.org, www.cdc.gov, or www.iata.org. In general, good respiratory and hand hygiene practices should always be encouraged, and people with febrile illnesses should postpone air travel whenever possible.

AIRCREW HEALTH

Aircrews, particularly of international fights, are at risk for the same illnesses to which other travelers are exposed. Because of their very short-term stays, and stays that are generally in major cities, they may not be as intensely exposed to some illnesses as others. However, their lifestyle may predispose them to other risks. Because of their frequent international travel, flight crews should receive health recommendations that are specifically geared to their travel patterns, itineraries, and lifestyles. For example, an international pilot flying frequently to sub-Saharan Africa would do well not to take routine anti-malarial medication, but should take precautions to avoid insect bites, may carry a self-treatment regimen if desired and if the layovers are extended, and should be instructed to seek medical attention immediately if a fever occurs. The medical department of international carriers should either be able to provide good information and appropriate immunizations to aircrew, or should have an arrangement with a travel clinic for appropriate education of flight crews.

Other than transmission of infectious agents, flight crews have other health concerns that though briefly mentioned here, are best reviewed in an occupational health setting. Issues that have surfaced with regard to pilot health have included the safety of refractive surgery, the use of serotonin re-uptake inhibitors, safety of pilots to fly with insulin-dependent diabetes mellitus or even with the human immunodeficiency virus, as well as issues related to pilot fatigue. Flight attendants' concerns have ranged from reproductive health problems, menstrual disorders, chronic back pain, to fears of an increased risk of breast cancer.

Epidemiological studies have shown an increased prevalence of malignant melanoma among flight crew members. This is thought to be a result of a lifestyle, allowing exposure to sunlight that is perhaps increased during layover periods.[34]

PASSENGER HEALTH

Introduction

Flying as a passenger should be no problem for the fit, healthy, and mobile individual. But for the passenger with certain pre-existing conditions, the cabin environment may exacerbate their underlying problems.

Although many problems relate to the physiological effects of hypoxia and expansion of trapped gases, it should be remembered that the complex airport environment can be stressful and challenging to the passenger, leading to problems before even becoming air-borne.

Although passengers with medical needs require medical clearance from the airline, passengers with disabilities do not. Disabled passengers do need to notify the requirement for special needs, such as wheelchair assistance or assignment of seats with lifting armrests, and this should be done at the time of booking.

An area of little exploration has been air travel stress and anxiety.[35] Whereas typical issues such as fear of flying have been addressed by the airlines in the past, problems that have surfaced related to terrorism and airline security have increased. Passenger lines, terminal crowding, lesser personal services due to cost-cutting, etc. have taken a toll on the ease in which air travel is currently perceived. Addressing these potential problems with the air traveler, particularly with those who have any underlying illness or general anxiety, is helpful.

Pre-flight assessment and medical clearance

The objectives of medical clearance are to provide advice to passengers and their medical attendants on fitness to fly, and to prevent delays and diversions of the flight as a result of deterioration in the passenger's well-being. It depends upon self-declaration by the passenger, and upon the attending physician having an awareness of the flight environment and how this may affect the patient's condition.

Most major airlines provide services for those passengers who require extra help, and most have a medical advisor to assess the fitness for travel of those with medical needs. Individual airlines work with their own guidelines, but these are generally based on those published by the Aerospace Medical Association on fitness for travel.[36] (Copies of the AsMA Guidelines may be obtained from the Association online at: www.asma.org or Tel: 703 739 2240.)

The International Air Transport Association (IATA) publishes a recommended Medical Information Form (MEDIF) for use by member airlines (Fig. 46.5). The MEDIF should be completed by the passenger's medical attendant and passed to the airline, or travel agent, at the time of booking to ensure timely medical clearance.

Medical clearance is required when:

- fitness to travel is in doubt as a result of recent illness, hospitalization, injury, surgery or instability of an acute or chronic medical condition
- special services are required (e.g. oxygen, stretcher or authority to carry or use accompanying medical equipment such as a ventilator or a nebulizer).

Medical clearance is not required for carriage of an invalid passenger outside these categories, although special needs (such as a wheelchair) must be reported to the airline at the time of booking. Cabin crew members are unable to provide individual special assistance to invalid passengers beyond the provision of normal in-flight service. Passengers who are unable to look after their own personal needs during flight (such as toileting or feeding) will be asked to travel with an accompanying adult who can assist with these needs.

It is vital that passengers remember to carry with them any essential medication, and not pack it in their checked baggage.

Deterioration on holiday or on a business trip of a previously stable condition – such as asthma, diabetes, or seizure disorder – can often give rise to the need for medical clearance for the return journey. A stretcher may be required, together with medical support, and this can incur considerable cost. It is important for all travelers to consider supplemental travel insurance, which includes provision for the use of a specialist repatriation company to provide the necessary medical support.

INCAPACITATED PASSENGERS HANDLING ADVICE
INCAD HANDLING INFORMATION

Answer all questions. Put a (X) in 'Yes' or 'No' boxes.
Use block letters or typewriter when completing this form

Part 1

To be completed by Sales Office/Agent

A Name/Initials/Title

B Proposed itinerary (airline(s), flight number(s) Class(es), date(s), segment(s), reservation status of continuous air journey)

Transfer from one flight to another often requires longer connecting time

C Nature of incapacitation

Medical clearance required? No ☐ Yes ☐

D Is stretcher needed on board? (all stretcher cases must be escorted) No ☐ Yes ☐

Request rate if unknown

E Intended escort (Name, sex, age, professional qualification, segments, if different from passenger). If untrained state 'Travel companion'

For blind and/or deaf state if escorted by trained dog

F Wheelchair needed? No ☐ Yes ☐

Wheelchair category ☐

Categories are
WCHR - can climb steps/walk cabin
WCHS - unable steps/can walk cabin
WCHC - immobile

Own wheelchair?	Collapsible?	Power Driven?	Battery type (Spillable)?
No ☐	No ☐	No ☐	No ☐
Yes ☐	Yes ☐	Yes ☐	Yes ☐

Wheelchairs with spillable batteries are 'restricted articles

G Ambulance needed? No ☐ Yes ☐

To be arranged by airline
No ☐ specify Ambul Company contact
Yes ☐ specify destination address

Request rate(s) if unknown

H Other ground arrangements needed? No ☐ Yes ☐

If yes, specify below and indicate for each item, (a) the arranging airline or other organisation, (b) at whose expense, and (c) contact addresses/phones where appropriate, or whenever specific persons are designated to meet/assist the passenger

1 Arrangements for delivery at airport of departure — No ☐ Yes ☐ Specify

2 Arrangements for assistance at connecting points — No ☐ Yes ☐ Specify

3 Arrangements for meeting at airport of arrival — No ☐ Yes ☐ Specify

4 Other requirements or relevant information — No ☐ Yes ☐ Specify

K Special in-flight arrangements needed, such as: special meals, special seating, leg rest, extra seat(s), special equipment etc.

(See 'Note(*)' at the end of Part 2 overleaf)

No ☐ Yes ☐

If yes, describe and indicate for each item, (a) segment(s) on which required (b) airline arranged or arranging third party, and (c) at whose expense. provision of special equipment such as oxygen etc. always requires completion of Part 2 overleaf.

L Does passenger hold a 'Frequent traveller's medical card' valid for this trip? (FREMEC) No ☐ Yes ☐

If yes, add below FREMEC data to your reservation requests.
If no, (or additional data needed by carrying airline(s)), have physician in attendance complete Part 2 overleaf.

FREMEC (FREMEC Nr) | (issued by) | (valid until) | (sex) | (age) | (incapacitation)

(incapacit. contd.) | (limitations)

Passengers declaration

I hereby authorize ______________________________
(name of nominated physician)

To complete Part 2 for the purpose as indicated overleaf and in consideration there of I hereby relieve that physician of his/her professional duty of confidentiality in respect of such information, and agree to meet such physician's fees in connection therewith.

Date: | Passenger's signature or Agent

Figure 46.5: International Air Transport Association (IATA) Medical Information Form (MEDIF).

Continued

Part 2 MEDIF Medical information sheet CONFIDENTIAL

This form is intended to provide confidential information to enable the airlines' medical departments to provide for the passenger's special needs.
To be completed by attending physician
- When fitness to travel is in doubt as evidenced by recent illness, hospitalisation, injury, surgery or instability.
- where special services are required, i.e. oxygen, stretcher, authority to carry accompanying medical equipment.

Completion of the form in block letters or by typewriter will be appreciated.

Airlines' ref code MEDA01	Patient's name, initial(s), sex			Age	
MEDA02	Attending physician Name and address				
	Telephone contact	Business	Home		
MEDA03	Medical data: Diagnosis in details (including vital signs)				
	Day/month/year of first symptoms		Date of diagnosis/injury	Date of operation	
MEDA04	Prognosis for the flight				
MEDA05	Contagious communicable disease?	No ☐	Yes ☐	Specify	
MEDA06	Would the physical and/or mental condition of the patient be likely to cause distress or discomfort to other passengers?	No ☐	Yes ☐	Specify	
MEDA07	Would the physical and/or mental condition of the patient be likely to cause distress or discomfort to other passengers?	Yes ☐	No ☐		
MEDA08	Can patient take care of his own needs on board unassisted* (including meals, visit to toilet, etc.)?	Yes ☐	No ☐	If not, type of help needed	
MEDA09	If to be escorted, is the arrangement proposed in part 1/E overleaf satisfactory for you?	Yes ☐	No ☐	If not, type of escort proposed	
MEDA10	Does patient need supplementary oxygen** equipment in flight? (if yes, state rate of flow, 2/41/min). Guidance: supplementary oxygen is not generally required unless dyspnoeic after walking 50 metres. (Charge £100 per journey)	Yes ☐	No ☐	If not, type of escort proposed	Litres per minute ☐ Continuous ☐ Intermittent ☐
MEDA11	Does patient need any medication*, other than self-administered, and/or the use of special apparatus such as a respirator, incubator etc.**	☐	☐		
MEDA12		☐	☐		
MEDA13	Does patient need hospitalisation? (If yes, indicate arrangements made or, if none were made indicate 'No action taken)	☐	☐		
MEDA14		☐	☐		
MEDA15	Other remarks or information in the interest of your patient's smooth and comfortable transportation:	None ☐	Specify if any**		
MEDA16	Other arrangements made by the attending physician				

Note (*): cabin attendents are not authorized to give special assistance to particular passengers, to the detriment of their service to other passengers. Additionally, they are trained only in first aid and are not permitted to administer any injection, or to give medication.

Important: Fees if any, relevant to the provision of the above information and for carrier - provided special equipment (**) are to be paid by the passenger concerned

Date:	Place:	Attending physician's signature

Figure 46.5:—cont'd International Air Transport Association (IATA) Medical Information Form (MEDIF).

Assessment criteria

In determining the passenger's fitness to fly, a basic knowledge of aviation physiology and physics can be applied. Any trapped gas will expand in volume by up to 30% during flight, and consideration must be given to the effects of the relative hypoxia encountered at a cabin altitude of up to 8000 ft above mean sea level. The altitude of the destination airport may also need to be taken into account in deciding the fitness of an individual to undertake a particular journey.

The passenger's exercise tolerance can provide a useful guide on fitness to fly; if unable to walk a distance >50 m without developing dyspnea, there is a risk that the passenger will be unable to tolerate the relative hypoxia of the pressurized cabin. More specific guidance can be gained from knowledge of the passenger's baseline sea level blood gas levels and hemoglobin value. A good source of guidance is provided by the British Thoracic Society website.[37]

Table 46.1 shows the guidelines recommended by one international carrier. This list is not exhaustive, and it should be remembered that individual cases might require individual assessment by the attending physician.

The prolonged period of immobility associated with long-haul flying can be a risk for those individuals predisposed to develop deep venous thrombosis (DVT). Pre-existing risk factors include:

- blood disorders and clotting factor abnormalities
- cardiovascular disease
- malignancy
- major surgery
- lower limb/abdominal trauma
- DVT history
- pregnancy
- estrogen therapy (including oral contraception and hormone replacement therapy)
- >40 years of age
- immobilization
- pathological body fluid depletion
- smoking
- obesity
- varicose veins.

Although many airlines promote lower limb exercise via the in-flight magazine or videos, and encourage mobility within the cabin, those passengers known to be vulnerable to DVT should seek guidance from their attending physician on the use of compression stockings and/or anti-coagulants. There is currently no evidence that flying, per se, is a risk factor for the development of DVT, but those at high risk should avoid any form of prolonged immobilization such as is associated with travel.[38]

CONSIDERATIONS OF PHYSICAL DISABILITY OR IMMOBILITY

In addition to the reduction in ambient pressure and the relative hypoxia, it is important to consider the physical constraints of the passenger cabin. A passenger with a disability must not impede the free egress of the cabin occupants in case of emergency evacuation.

There is limited leg space in an economy class seat and a passenger with an above-knee leg plaster or an ankylosed knee or hip may simply not fit in the available space. The long period of immobility in an uncomfortable position must be taken into account, and it is imperative to ensure adequate pain control for the duration of the journey, particularly following surgery or trauma.

Even in the premier class cabins with more available legroom, there are limits to space. To avoid impeding emergency egress, immobilized or disabled passengers cannot be seated adjacent to emergency exits, despite the availability of increased leg room at many of these positions. Similarly, a plastered leg cannot be stretched into the aisle because of the conflict with safety regulations.

There is limited space in aircraft toilet compartments and if assistance is necessary, a traveling companion is required.

The complexities of the airport environment should not be underestimated, and must be considered during the assessment of fitness to fly. The formalities of check-in and departure procedures are demanding and can be stressful, and this can be compounded by illness and disability, as well as by language difficulties or jet lag.

The operational effect of the use of equipment such as wheelchairs, ambulances, and stretchers must be taken into account, and the possibility of aircraft delays or diversion to another airport must be considered. It may be necessary to change aircraft and transit between terminals during the course of a long journey, and landside medical facilities will not be available to a transiting passenger.

There is often a long distance between the check-in desk and the boarding gate. Not all flights depart from or arrive to jetties, and it may be necessary to climb up or down stairs and board transfer coaches. Passengers should specify the level of assistance required when booking facilities such as wheelchairs.

OXYGEN

In addition to the main gaseous system, all commercial aircraft carry an emergency oxygen supply for use in the event of failure of the pressurization system or during emergencies such as fire or smoke in the cabin. The passenger supply is delivered through drop-down masks from chemical generators or an emergency reservoir, and the crew supply is from oxygen bottles strategically located within the cabin. The drop-down masks are automatically released en masse (the so-called 'rubber jungle') in the event of the cabin altitude exceeding a pre-determined level of between 10 000 and 14 000 ft. This passenger emergency supply has a limited duration if provided by chemical generators, usually in the region of 10 min. The flow rate is between 4 and 8 L (NTP)/min, and is continuous once the supply is triggered by the passenger pulling on the connecting tube. Oxygen supplied from an emergency reservoir is delivered to the cabin via a 'ring main', and in some aircraft it is possible to plug a mask into this ring main to provide supplementary oxygen for a passenger.

Sufficient first-aid oxygen bottles are carried to allow the delivery of oxygen to a passenger in case of a medical emergency in-flight, at a rate of 2 or 4 L (NTP)/min. This cannot be used to provide a pre-meditated supply for a passenger requiring it continuously throughout a journey, however, since it would then not be available for emergency use.

If a passenger has a condition requiring continuous ('scheduled') oxygen for a journey, this needs pre-notification to the airline at the time of booking the ticket. Most airlines charge a fee: one major British international airline charges GB£100 (US$170, Euro€146) per sector, whether the supply is derived from gaseous bottles or via a mask plugged into the ring main. For US carriers, a fee of approximately US$100 (€85) is charged for providing oxygen during flight. Some airlines also allow passengers to use their own portable oxygen concentrators, provided the unit meets certain specifications. An additional fee may be charged for medical clearance by an airline representative. Passengers who require continuous oxygen during travel should be made aware that airlines provide oxygen service only during the flight, and not during the time spent in the airport terminal. Passengers need to make arrangements for oxygen to be supplied at their destination upon arrival.

Oxygen bottles, regulators and masks must meet minimum safety standards set by the regulatory authorities, and the oxygen must be of 'aviation' quality, which is a higher specification than 'medical' quality.

Table 46.1 Guidelines for medical clearance

Category	Do not accept	Remarks
Cardiovascular disorders	Uncomplicated myocardial infarction within 7 days	Myocardial infarction < 21 days requires MEDIF assessment
	Uncontrolled heart failure	
	Open heart surgery within 10 days	This includes CABG and valve surgery. MEDIF assessment required up to 21 days postoperatively
	Angioplasty – No stenting 3 days; with stenting 5 days	Transpositions, ASD/VSD, transplants, etc. will require discussion with airline medical advisor
Circulatory disorders	Active thrombophlebitis of lower limbs	
	Bleeding/clotting conditions	Recently commenced anti-coagulation therapy requires assessment
	Blood disorders	
	Hb <7.5 g/dL	MEDIF assessment required for Hb < 10 g/dL
	History of sickle cell crisis within 10 days	
Respiratory disorders	Pneumothorax which is not fully inflated, or within 14 days after full inflation	
	Major chest surgery within 10 days	MEDIF assessment required up to 21 days postoperatively
	If breathless after walking 50 m on ground or on continuous oxygen therapy on ground	Consider mobility and all aspects of total journey
Gastrointestinal disorders	General surgery within 10 days	Laparoscopic investigation may travel after 24 h if all gas absorbed. Laparoscopic surgery requires MEDIF up to 10 days
	GI tract bleeding within 24 h	MEDIF required up to 10 days
CNS disorders	Stroke including subarachnoid hemorrhage within 3 days	Consider mobility/oxygenation aspects. MEDIF up to 10 days
	Generalized seizures within 24 h	Petit mal or minor twitching – common sense prevails
	Brain surgery within 10 days	Cranium must be free from air
ENT disorders	Otitis media and sinusitis	
	Middle ear surgery within 10 days	
	Tonsillectomy within 1 week	
	Wired jaw, unless escorted and with wire cutters	If fitted with self quick release wiring may be acceptable without escort
Eye disorders	Penetrating eye injury/intraocular surgery within 1 week	If gas in globe, total absorption necessary – may be up to 6 weeks, specialist check necessary
Acute psychiatric disorders	Unless escorted, with appropriate medication carried by escort, competent to administer such	MEDIF required. Medical, nursing or highly competent companion/relative escort
Pregnancy	After end of 36th week for single, uncomplicated After end of 32nd week for multiple, uncomplicated	Passenger advised to carry medical certificate
Neonates	Within 48 h	Accept after 48 h if no complications present
Infectious disease	If in infectious stage	As defined by the American Public Health Association (Benenson)
Terminal illness	Until individual case assessed by airline medical advisor	Individual case assessment
Decompression	Symptomatic cases (bends, staggers, etc.) within 10 days	May need diving or aviation physician advice
Scuba diving	Within 24 h	
Fractures in plaster	Within 48 h unless splint bi-valved	Extent, site, and type of plaster may allow relaxation of guidelines. Exercise caution with fiberglass casts
Burns	Consult airline medical advisor	

Regulations regarding in-flight oxygen use are in flux. For further information regarding therapeutic oxygen for airline passengers, see websites: www.medaire.com *and* www.airsep.com

IN-FLIGHT MEDICAL EMERGENCIES

An in-flight medical emergency is defined as a medical occurrence requiring the assistance of the cabin crew. It may or may not involve the use of medical equipment or drugs, and may or may not involve a request for assistance from a medical professional traveling as a passenger on the flight. It can be something as simple as a headache, or a vaso-vagal episode, or something major, such as a myocardial infarction or impending childbirth.

The incidence is comparatively low, although the media impact of an event can be significant. One major international airline recently reported 3022 incidents occurring in something over 34 million passengers carried in 1 year. The breakdown of these incidents into generalized causes is shown in Table 46.2.[39,40]

Table 46.2 In-flight medical incidents reported in 1 year by a major airline

Type of medical incident	(%)
Gastrointestinal system	22.3
Cardiovascular system	21.8
Musculoskeletal system/skin	13.4
Central nervous system	15.5
Respiratory system	10.2
Urogenital system	3.3
Metabolic system	2.5
Oto-rhino-laryngology (ENT)	1.4
Miscellaneous	9.6

Total of 3022 incidents in 34 million passengers.

The top six in-flight emergency medical conditions reported by the same airline are shown in Table 46.3.[39,40] Any acute medical condition occurring during the course of a flight can be alarming for the passenger and crew because of the remoteness of the environment. Cabin crew members receive training in advanced first aid and basic life support and the use of the emergency medical equipment carried on board the aircraft. Many airlines give training in excess of the regulatory requirement, particularly when an extended range of medical equipment is carried.

GOOD SAMARITANS

Although the crew are trained to handle common medical emergencies, in serious cases they may request assistance from a medical professional traveling as a passenger. Such assisting professionals are referred to as 'Good Samaritans'. Cabin crew members attempt to establish the bona fide of medical professionals offering to assist, but much has to be taken on trust.

The international nature of air travel can lead to complications in terms of professional qualification and certification, specialist knowledge, and professional liability. An aircraft in flight is subject to the laws of the state in which it is registered, although when not moving under its own power (i.e. stationary at the airport) it is subject to the local law. In some countries, it is a statutory requirement for a medical professional to offer assistance to a sick or injured person (e.g. France), whereas in other states no such law exists (e.g. UK or USA).

Some countries (e.g. USA) have enacted a Good Samaritan law, whereby an assisting professional delivering emergency medical care within the bounds of his or her competence, is not liable for prosecution for negligence. In the UK, the major medical defense insurance companies provide indemnity for their members acting as Good Samaritans.

Some airlines provide full indemnity for medical professionals assisting in response to a request from the crew, whereas other airlines take the view that a professional relationship is established between the sick passenger and the Good Samaritan and any liability lies within that relationship. At the time of writing, there has been no case of successful action against a Good Samaritan providing assistance on board an aircraft.

Recognition by the airline of the assistance given by the Good Samaritan is complicated by the special nature of the relationship between the professional, the patient, and the airline. Indemnity, whether provided by the airline or the professional's defense organization, depends upon the fact that a Good Samaritan act is performed.

Table 46.3 Six most common in-flight medical incidents reported in 1 year by a major airline

Type of medical incident	(%)
Faint	14.9
Diarrhea	11.5
Head injury	6.3
Vomiting	6.1
Collapse	5.4
Asthma	4.9

Total of 3022 incidents in 34 million passengers.

If a professional fee is claimed or offered, the relationship moves away from being that of a Good Samaritan act to one of a professional interaction with an acceptance of clinical responsibility. This implies that the professional is suitably trained, qualified, and experienced to diagnose, treat and follow-up the particular case, and the Good Samaritan indemnity provision no longer applies.

Follow-up of the outcome for the passenger after disembarkation is frequently difficult, because the sick passenger is no longer in the care of the airline and becomes the responsibility of the receiving hospital or medical practitioner.

AIRCRAFT MEDICAL DIVERSION

Responsibility for the conduct of the flight rests with the aircraft captain who makes the final decision as to whether or not an immediate unscheduled landing or diversion is required for the well-being of a sick passenger. The captain has to take into account operational factors as well as the medical condition of the sick passenger.

In practice, it is rarely possible to land immediately, even if a suitable airport is in the immediate vicinity. The aircraft has to descend from cruising altitude, possibly jettison fuel to reduce to landing weight, and then fly the approach procedure to land.

Consideration has to be given to the availability of appropriate medical facilities, and in many cases, it is of greater benefit for the sick passenger to continue to the scheduled destination where the advantage of appropriate facilities will outweigh the risks of continuing the flight.

Operational factors to be considered include the suitability of an airport to receive the particular aircraft type. The runway must be of sufficient length and load-bearing capacity, the terminal must be able to accommodate the number of passengers on the flight, and if the crew go out of duty time, there must be sufficient hotel accommodation to allow an overnight stay of crew and passengers.

The cost to the airline may be substantial, including the effects of aircraft and crew unavailability for the next scheduled sector, as well as the direct airport and fuel costs of the diversion. In making the decision whether or not to divert, the captain will take advice from all sources. If a Good Samaritan is assisting, he or she has an important role to play, perhaps in radio consultation with the airline medical advisor.

TELEMEDICINE

Many airlines use an air-to-ground link, which allows the captain and/or the Good Samaritan to confer with the airline medical adviser regarding the diagnosis, treatment, and prognosis of the sick passenger. The airline operations department is also involved in the decision-making process. Some airlines maintain a worldwide database of medical facilities available at or near the major airports; others

Table 46.4 Federal aviation regulations, Part 121: First aid and emergency medical kits

First aid kits

Approved first aid kits required by β121.309 must meet the following specifications and requirements:

1. Each first aid kit must be dust and moisture proof, and contain only materials that either meet Federal Specification GG-K-291a, as revised, or are approved.
2. Required first aid kits must be distributed as evenly as practicable throughout the aircraft and be readily accessible to the cabin flight attendants.
3. The minimum number of first aid kits required is set forth in the following table:

No. of passenger seats	*No. of first aid kits*
0–50	1
51–150	2
151–250	3
More than 250	4

4. Except as provided in paragraph 5, each first aid kit must contain at least the following or other approved contents:

Contents	*Quantity*
Adhesive bandage compresses, 10-inch	16
Antiseptic swabs	20
Ammonia inhalants	16
Bandage compresses, 4-inch	8
Triangular bandage compresses, 10-inch	5
Burn compound, 1/8-ounce or an equivalent of other burn remedy	6
Arm splint, non-inflatable	1
Leg splint, non-inflatable	1
Roller bandage, 4-inch	4
Adhesive tape, 1-inch standard roll	2
Bandage scissors	1

5. Arm and leg splints that do not fit within a first aid kit may be stowed in a readily accessible location that is as near as practicable to the kit.

Emergency medical kits

The approved emergency medical kit required by β121.309 for passenger flights must meet the following specifications and requirements:

1. Approved emergency medical equipment shall be stored securely so as to keep it free from dust, moisture, and damaging temperatures.
2. One approved emergency medical kit shall be provided for each aircraft during each passenger flight and shall be located so as to be readily accessible to crew members.
3. The approved emergency medical kit must contain, as a minimum, the following appropriately maintained contents in the specified quantities.

Contents	*Quantity*
Sphygmomanometer	1
Stethoscope	1
Airways, oropharyngeal (3 sizes)	3
Syringes (sizes necessary to administer required drugs)	4
Needles (sizes necessary to administer required drugs)	6
50% Dextrose injection 50 cc	1
Epinephrine 1:1000, single dose ampoule or equivalent	2
Diphenhydramine HCl injection, single dose ampoule or equivalent	2
Nitroglycerin tablets	10
Basic instructions for use of the drugs in the kit	11

subscribe to a third party provider giving access to immediate medical advice and assistance with arranging emergency medical care for the sick passenger at the diversion airport.

The link from the aircraft is made using either radio-telephone voice or datalink (VHF or ACARS), high-frequency radio communication (HF) or a satellite communication system (Satcom). Satcom is installed in newer, long-range aircraft, and is gradually replacing HF as the industry norm for long-range communication. The advantage is that Satcom is unaffected by terrain, topography or atmospheric conditions, and allows good transmission of voice and data from over any point on the globe. Digitization and telephone transmission of physiological parameters is a well established practice, particularly in remote areas of the world. An aircraft cabin at 37 000 ft (11 500 m) can be considered a remote location in terms of availability of medical support, and the digital technology used in Satcom is similar to that used in modern ground-to-ground communication. The advent of Satcom has enabled the development of air-to-ground transmission to assist in diagnosis. Pulse oximetry and ECG are examples of data that can assist the medical advisor to give appropriate advice to the aircraft captain, although the cost/benefit analysis has to be weighed very carefully.[40]

AIRCRAFT EMERGENCY MEDICAL EQUIPMENT

National regulatory authorities stipulate the minimum scale and standard of all equipment to be carried on aircraft operating under their jurisdiction, which includes emergency medical equipment. These standards stipulate the minimum requirement, although in practice many airlines carry considerably more equipment.

Tables 46.4 and 46.5 give the minimum standard of equipment mandated by the Federal Aviation Administration (FAA) to be carried by aircraft registered in the USA, while Table 46.6 gives the standard determined by the Joint Aviation Authorities (JAA) for aircraft registered in European states.

In determining the type and quantity of equipment and drugs to include in the medical kits, the airline must fulfill the statutory requirements laid down by the regulatory authority. Other factors to be considered are:

- The route structure and stage lengths flown. Different countries of the world vary in their regulations on what might be imported and exported, particularly in terms of drugs. For example, it is illegal to import morphine derivatives into the USA, even if securely locked in a medical kit

Table 46.5 US Aviation medical assistance act (1998)

Rule issued by Federal Aviation Administration (FAA), April 2001
US Aircraft weighing >7500 lb and having at least one flight attendant must carry an automated external defibrillator (AED) and enhanced medical kit (EMK) on all domestic and international flights within 3 years.
The following items will be added to each EMK: Oral antihistamine Non-narcotic analgesic Aspirin Atropine Bronchodilator inhaler Lidocaine and saline i.v. administration kit with connectors CPR masks
An EMK is already equipped with Sphygmomanometer (measures blood pressure) Stethoscope Three sizes of oral airways (breathing tubes) Syringes Needles 50% dextrose injection (for hypoglycemia or insulin shock) Epinephrine (for asthma or acute allergic reactions) Diphenhydramine (for allergic reactions) Nitroglycerin tablets (for cardiac-related pain) Basic instructions on the use of the drugs Latex gloves
All crew members will receive initial training on the EMK and on the location, function, and intended operation of an AED. Flight attendants will receive initial and recurrent training in CPR and on the use of AEDs. Medical personnel are frequently onboard and can assist fellow passengers during an in-flight medical event. In addition, a 'Good Samaritan' provision in the aviation medical assistance act of 1998 limits the liability of air carriers and non-employee passengers unless the assistance is grossly negligent or willful misconduct is evident.

- Passenger expectations. Premier class business passengers from the developed world expect a higher standard of care and medical provision than passengers traveling on a relatively inexpensive package holiday flight
- Training of cabin crew. The crew must have a knowledge and understanding of the kit contents, for use by themselves or in assisting a Good Samaritan. They must be proficient in first aid, resuscitation and basic life support
- Differences in medical cultures. Ideally, the kit contents should be familiar to any Good Samaritan, irrespective of nationality or training. Some authorities require information and drug names to be given in more than one language
- Equipment and drugs appropriate for likely medical emergencies. It is important to audit the incidence and outcome of in-flight medical emergencies and maintain a review of the kit content. This review should also take into account changes in medical practice
- Space and weight. The medical equipment must be accessible, but securely stowed. Some airlines divide the equipment and drugs between basic first-aid kits, which are readily accessible on the catering trolleys, and a more comprehensive emergency medical kit that is sealed and stowed with other emergency equipment. Space and weight are always at a premium within the cabin, and the medical kits must be as light and compact as possible
- Shelf life and replenishment. A tracking system for each kit must be in place to ensure that contents have not exceeded their designated shelf life. Similarly, after use of a kit, there has to be a procedure for replenishment. In practice, the aircraft can depart if the kit contents meet the statutory minimum, even though drugs or equipment have been used from the non-statutory part of the kit. Many airlines subcontract the tracking and replenishment to a specialist medical supply company.

Table 46.6 European joint aviation requirements: JAR-OPS 1, sub-part L

First aid kits
The following should be included in the first aid kits: Bandages (unspecified) Burns dressings (unspecified) Wound dressings, large and small Adhesive tape, safety pins and scissors Small adhesive dressings Antiseptic wound cleaner Adhesive wound closures Adhesive tape Disposable resuscitation aid Simple analgesic (e.g. paracetamol) Antiemetic (e.g. cinnarizine) Nasal decongestant First-aid handbook Splints, suitable for upper and lower limbs Gastrointestinal antacid + Anti-diarrheal medication (e.g. Loperamide +) Ground/Air visual signal code for use by survivors Disposable gloves
A list of contents in at least two languages (English and one other). This should include information on the effects and side-effects of drugs carried.
Note: An eye irrigator, while not required to be carried in the first aid kit should, where possible, be available for use on the ground.
In addition, for aeroplanes with more than nine passenger seats installed, an emergency medical kit must be carried.
The following should be included in the emergency medical kit: Sphygmomanometer – non-mercury Stethoscope Syringes and needles Oropharyngeal airways (two sizes) Tourniquet Coronary vasodilator (e.g. nitro-glycerine) Anti-spasmodic (e.g. hyoscine) Epinephrine 1:1000 Adrenocortical steroid (e.g. hydrocortisone) Major analgesic (e.g. nalbuphine) Diuretic (e.g. furosemide) Antihistamine (e.g. diphenhydramine hydrochloride) Sedative/anticonvulsant (e.g. diazepam) Medication for hypoglycemia (e.g. hypertonic glucose) Antiemetic (e.g. metoclopramide) Atropine Digoxin Uterine contractant (e.g. ergometrine/oxytocin) Disposable gloves Bronchial dilator, including an injectable form Needle disposal box Anti-spasmodic drug Catheter
A list of contents in at least two languages (English and one other). This should include information on the effects and side-effects of drugs carried.

RESUSCITATION EQUIPMENT

Although basic cardiopulmonary resuscitation (CPR) techniques are an essential part of cabin crew training, the outcome of an in-flight cardiac event may be improved if appropriate resuscitation equipment is available. This can range from a simple mouth-to-mouth faceguard, to a resuscitation bag and mask and airway, to an endotracheal tube and laryngoscope, to an automatic external defibrillator (AED).

The decision on the scale of equipment to be carried has to take account of the same parameters used in determining the content of the emergency medical kits (Table 46.5).

In addition, a cost/benefit analysis has to balance the cost of acquisition, maintenance and training against the probability of need and the expectation of the traveling public.

The European Resuscitation Committee and the American Heart Association endorse the concept of early defibrillation as the standard of care for a cardiac event both in and out of the hospital setting. However, the protocol includes early transfer to an intensive care facility for continuing monitoring and treatment, which is not always possible in the flight environment.

Despite this inability to complete the resuscitation chain, it is becoming increasingly common for commercial aircraft to be equipped with AEDs and for the cabin crew to be trained in their use. This has been mandated in the USA by the FAA (Table 46.5). Experience of those airlines which carry AEDs indicates that there may be benefits to the airline operation as well as to the passenger. Some types of AED have a cardiac monitoring facility, and this can be of benefit in reaching the decision on whether or not to divert. For example, there is no point in initiating a diversion if the monitor shows asystole, or if it suggests that the chest pain is unlikely to be cardiac in origin.

Lives have been saved by the use of AEDs on aircraft and diversions have been avoided, so it could be argued that the cost/benefit analysis is weighted in favor of carrying AEDs as part of the aircraft medical equipment. Nonetheless, it is important that unrealistic expectations are not raised. An aircraft cabin is not an intensive care unit and the AED forms only a part of the first aid and resuscitation equipment.

Many airlines have in place a procedure for the follow-up of crew members involved in a distressing event, such as a serious medical emergency. This can be valuable in avoiding long-term post-traumatic stress disorder, and also in reinforcing the training that the crew member has already undergone.

CONCLUSION

The pressurized aircraft cabin provides protection against the hostile environment encountered at cruising altitudes.

- Although the partial pressure of oxygen is less than at sea level, it is more than adequate in a pressurized aircraft cabin for normal healthy individuals
- The cabin air, although dry, does not cause systemic dehydration and harm to health. Dry skin and eyes can lead to discomfort, which can be alleviated by the use of moisturizing creams and eye drops
- Although up to half of the air in modern pressurized aircraft is recirculated, the amount of fresh air available to each occupant exceeds that available in air-conditioned buildings. Recirculating the air has the advantage of reducing cold draughts and increasing the humidity
- In modern aircraft, all the recirculated air is passed through high-efficiency particulate filters which remove >99% of particles, including bacteria and viruses
- There is an extremely low probability of airline passengers or crew suffering any abnormality or disease as a result of exposure to cosmic radiation.

The passenger cabin of a commercial airliner is designed to carry the maximum number of passengers in safety and comfort, within the constraints of cost-effectiveness. It is incompatible with providing the facilities of an ambulance, an emergency room, an intensive care unit, a delivery suite, or a mortuary.

The ease and accessibility of air travel to a population of changing demographics inevitably means that there are those who wish to fly, who may not cope with the hostile physical environment of the airport, or the hostile physiological environment of the pressurized passenger cabin. It is important for medical professionals to be aware of the relevant factors, and for unrealistic public expectations to be avoided.

Transmission aboard aircraft of illnesses, such as tuberculosis, SARS and other respiratory diseases, has been reported, but is infrequently documented and probably rare. There is no evidence that a properly functioning environmental control system contributes to increased disease transmission aboard an aircraft.

Most airlines have a medical advisor who may be consulted before flight to discuss the implications for a particular passenger. Such pre-flight notification can prevent the development of an in-flight medical emergency that is hazardous to the passenger concerned, inconvenient to fellow passengers, and expensive for the airline.

For those with disability, but not an acute medical problem, pre-flight notification of special needs and assistance will reduce the stress of the journey and enhance the standard of service delivered by the airline.

The importance of adequate medical insurance coverage for all travelers cannot be over-emphasized. Finally, as is the case in commercial aviation, there is a continuing audit of activity and an ongoing risk/benefit analysis. The industry is under constant evolution, and is now truly global in its activity. Application of basic physics and physiology, and an understanding of how this may affect underlying pathology, will minimize the medical risks to the traveling public.[18]

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