HEALTH ISSUES OF AIR TRAVEL

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Abstract  Every day in the United States the airline industry boards over 1.7 million passengers for a total of 600 million passengers per year. As these passengers enter the cabin of their aircraft few are aware of the artificial environment that will protect them from the hazards of flight. Passengers are exposed to reduced atmospheric pressure, reduced available oxygen, noise, vibration, and are subject to below zero temperatures that are only a quarter inch away—the thickness of the aircraft’s skin. Over the past decade there have been both technical and lay articles written on the perception of poor cabin air quality. Studies have, in part, supported some of those concerns, but, in general, the air quality exceeds that found in most enclosed spaces on terra firma.

Since the events of September 11th, passengers have not only been exposed to the physical stress of flight, but also to social and emotional stress preceding departure. There has been a significant increase in air rage on board aircraft, which poses a threat to flight safety and a fear of harm to passengers and crew. The phrase “economy class syndrome” has received popular press attention and refers to the possibility of deep vein thrombosis (DVT) in the tight confines of an aircraft cabin. Studies have been conducted that demonstrate DVT can occur in flight just as it occurs in other modes of transportation or with prolonged sitting.

In part, because of the stress related to commercial flight it is not a mode of transportation for everyone. Certain cardiovascular, pulmonary, and neuropsychiatric conditions are best left on the ground. Although medical problems and death are rare in flight, they do occur, and one major airline reported 1.52 medical diversions per billion revenue passenger miles flown. To provide medical support at 36,000 ft (11,000 m) most airlines now carry on-board medical kits as well as automatic external defibrillators. A recent survey conducted by a major airline revealed that there was at least one physician on 85% of all its flights.

Both passenger and cargo aircraft have proven to be vectors of disease in that they transport humans, mosquitoes, and other insects and animals who, in turn, transmit disease. Transmission to other passengers has occurred with tuberculosis and influenza. Vectors for yellow fever, malaria, and dengue have been identified on aircraft. Although there are numerous health issues associated with air travel they pale in comparison to the enormous benefits to the traveler, to commerce, to international affairs, and to the public’s health.
INTRODUCTION

For many, air travel is a way of life. The “road warrior” must frequently fly to meet the commitments of employment. Others fly quickly and dependably to a vacation holiday, to visit family and friends, to attend a celebration or funeral, or to make that necessary fast trip to the new job, to college, or simply to exercise a quick get-away from the mundane activities of daily living. In 2000, the United States airline industry boarded over 1.7 million passengers every day for a total of over 600,000,000 travelers flying that year (5). This is equivalent to the population of the entire nation taking several flights during the year.

The United States has 80% of the world’s aviation activity and carries more than one half of the world’s airline passengers (6). The passenger may be boarding a regional flight or shuttle and will be airborne for only 30 minutes or could perhaps board an international flight departing for Australia for a nonstop 16-h test of health and endurance. Normally, passengers board aircraft without their health problems and medications known to airline personnel, and unfortunately nonsophisticated travelers may board aircraft without any knowledge of the hazards of the flight environment.

THE FLIGHT ENVIRONMENT

There are at least two significant components to the flight environment: the environment that is associated with the physics of aviation, and the immediate environment of a passenger housed in an aircraft’s cabin.

The Aviation Environment

Modern jet airliners including regional, turbo prop aircraft operate in an environment that is potentially hazardous to humankind. Although aircraft depart and return to terra firma, they generally operate at altitudes between 10,000 ft and 50,000 ft (3,000–15,200 m) in an outside environment that ranges from uncomfortable to exceedingly hostile. There are at least four potential stressors present in the aviation environment that require protection to passengers:

1. Reduced atmospheric pressure
2. Reduced available oxygen (hypoxia)
3. Noise and vibration
4. Subfreezing temperatures

ATMOSPHERIC PRESSURE At sea level the weight of a column of gas extending into the stratosphere weighs approximately 14.7 pounds per square inch (psi) and thus forms a surrounding pressure on anyone or anything in that environment. Ascending from sea level to 1000 ft (300 m) reduces the pressure to just above 14 psi. At 18,000 ft (6000 m) the surrounding air pressure is reduced by half to
7.35 psi. The atmospheric pressure continues to fall as one ascends until at 50,000 ft (15,200 m) the air pressure is only 1.8 psi. The stress of pressure differences comes to bear when the passenger is in a shirtsleeve environment at sea level pressure and suddenly, because of a sudden change in circumstances, is now at 18,000 ft surrounded by only half the environment gas pressure; this results in the sudden expansion of gas in the sinuses, middle ear, lungs, and intestines until the gas can be released. If the gas is trapped this will result in discomfort, pain, or even death. Gas expansion follows Boyle’s law which states in part, “... the volume of a given mass of gas varies inversely as its pressure—as the pressure increases the volume decreases...” Thus a flexible container similar to a balloon containing a gas will expand in volume in proportion to the drop in pressure of the surrounding gas.

REDUCED OXYGEN  However, there is another characteristic of the lower pressure that can be more important, and which is the reality that the atmospheric gas is made up of 21% oxygen and 78% nitrogen with a combination of rarer gases and water thrown in. As you ascend in altitude and the surrounding gas pressure drops, the percentage of the constituent gases remains the same; that is, it was 21% at sea level and continues to be 21% at 18,000 or even 50,000 ft. In the case of oxygen, even though the 21% remains the same, the amount of the total gas is significantly reduced to the point that reduction in oxygen may result in hypoxia. For example, the partial pressure of oxygen at sea level is 160 mmHg, at 10,000 ft it is 110 mmHg, and it falls to 80 mmHg at 18,000 ft and 60 mmHg at 25,000 ft.

LOW TEMPERATURE  Another environmental hazard that worsens with increasing altitude is the significant reduction in environmental temperature. On a summer day many have enjoyed the cool refreshing temperature of a mountain drive as the temperature drops the higher one climbs. As we ascend in an aircraft the temperature drops in a generally predicted fashion known as the lapse rate, which represents a 3.6°F (2°C) drop for each thousand feet of ascent. The outside air temperature of an aircraft flying at 33,000 ft (10,000 m) can approach −50°F (−46°C).

To protect the crew and passengers from the hazards of hypoxia, diminished atmospheric pressure, and frigid temperatures, modern jet aircraft have a pressurized cabin to maintain a safe and comfortable flight.

The Cabin Environment

Modern jet airliners are required by the Federal Aviation Administration (FAA) to provide cabin pressurization adequate to maintain the internal environment of no higher than 8000 ft equivalent altitude, even if the aircraft is flying at 35,000 ft or higher. This cabin altitude was selected over 50 years ago when most passengers were expected to be healthy and fit and not expected to have any adverse health outcomes from the mild drop in available oxygen at this cabin altitude. Further, the change in atmospheric pressure was not expected to cause any great concern
as long as people could ventilate body cavities such as the sinuses and middle ear. At this cabin altitude the oxygen level circulating in the arterial blood (Pao₂) drops to about 69 mmHg from a sea level value of 103 mmHg, representing a drop in oxygen blood saturation to 90% from a sea level of 97%.

To maintain an appropriate pressure level in the cabin, outside air is compressed by the jet engines and transferred into the cabin. By adjusting a relief valve on the aircraft, the cabin pressure is maintained at a set level. Even though the jet aircraft is flying at an altitude where the outside air temperature may be as low as −50°F, when the air is compressed, it is heated and must be properly conditioned before entering the cabin. This process dries out the air or reduces its humidity before it is introduced into the pressurized cabin.

With potentially hundreds of people in the aircraft cabin breathing the same air, ventilation becomes critical to eliminate contaminants and provide environmental comfort. In today's aircraft 50% fresh air is introduced and added to 50% recirculated air. This compares to the average commercial building of 20% fresh air to 80% recirculated air, but of course the population density is much higher in an aircraft as compared to a building.

**CABIN AIR QUALITY** Over the past decade there have been a number of technical papers and journal articles written on the perception of poor cabin air quality (12, 15, 26). The compressed air used to ventilate the cabin has a low relative humidity typically found to be between 5% and 25% (5). Complaints about poor cabin air environments include dryness, stuffy air, odor, tobacco smoke, temperature discomfort, and draft. Ozone was thought to be one of the contaminants that contributed to the complaints about cabin air quality; however, when the pressurized fresh air is conditioned it passes through a catalytic ozone converter, which removes ozone. Further, a high efficiency particulate air filter (HEPA) captures particles that measure down to 0.3 μm with 99.97% efficiency, and this is followed in the air stream by a charcoal filter to remove volatile compounds such as hydrocarbons. Before most airline companies banned smoking on aircraft the majority of complaints about air quality were focused on this preventable source of cabin air contamination. However, there are incidences when fumes, vapors, and smoke enter the cabin and become a source of irritation and poor air quality. There are a number of sources of volatile organic compounds that may compromise cabin air quality such as: off-gassing from materials; food and beverages; pesticides; perfumes; paints; cleaning compounds; contaminants from ground operations, such as exhaust from trailing aircraft, de-icing chemicals, and petroleum products, owing to machine seal failure. Should a mechanical problem occur in one of the air compressing components such as an O-ring breakdown, oil can leak into the air compression system. Because the air in the compressor is very hot, pyrolysis of the oil may occur generating smoke and other volatile organic compounds. Investigations in Australia of an aircraft that generated frequent air quality complaints from both cockpit and cabin crews focused on tricresyl phosphate, a component of the aircraft’s engine oil.
Because there is evidence that insect disease vectors, particularly mosquitoes, may be imported into countries aboard aircraft, several nations insist that aircraft landing in their country must undergo disinsection (i.e., the application of an insecticide on board an aircraft to kill insects). Typically this is performed by the aircrew who discharge cans of aerosol spray of insecticides on some portion of the flight. When this occurs aboard a passenger aircraft it becomes one additional source of contamination that can degrade cabin air quality (25).

ADVERSE HEALTH EFFECTS OF COMMERCIAL FLIGHT

It is more appropriate to consider the total experience of passengers flying, not simply the experience of flight. Since the tragic events of September 11, 2001 the “hassle factor” of preboarding has grown enormously with stress manifested by anxiety, anger, frustration, and depression. Once on board, the passenger is crowded into a long tube to push and shove to find space in the overhead bins or under the seat for carry-on luggage. When one is at last seated, one finds that there are only inches between the seat and the back of the seat in front. Once airborne passengers breathe air somewhat depleted in oxygen and so low in humidity that mucous membranes in the nose and throat become dry and irritated. Passengers sit tightly buckled in the seats, where they are exposed to the physical stress of noise and vibration and occasional disruptions in the flight path sufficient to induce motion sickness. Postflight a passenger finds himself in, say, Europe after an eight-hour flight, across six time zones, with arrival at 10:00 am while his body remains convinced that he should still be tucked cozily in bed at 4:00 am. This desynchronization of circadian rhythms certainly contributes to fatigue and “brain fog” and causes passengers to appear not too cheerful when anticipating the start of a new business day.

Pre-Departure Stress

It seems like years ago when one could arrive at an airport, move quickly through the ticket line and baggage check, clear security, and board the aircraft in only 30–40 minutes. One is now advised to arrive at the airport two hours in advance and is frequently met with lines at each stage of the ticketing, security, and boarding process. At times one finds that things like fingernail clippers, laser pointers, electric toothbrushes, and camera tripods are no longer permitted in the passenger compartment. Once the baggage is scanned one may be selected to have the piece physically inspected, which is followed by one’s shoes, and there is always the possibility that one could prepare to board the aircraft and be pulled aside to have everything inspected a second time. This preflight process is no longer casual or relaxing but generates irritation, anxiety, frustration, and psychosocial stress.

An expression of the psychosocial stress can become evident once the aircraft is airborne and has been identified in the popular press as air rage. Reports from the aviation industry have revealed that air rage incidences are rapidly increasing...
and have approached an estimate of 5000 per year (24). This poses a serious threat to flight safety and produces fear of personal harm for those in the aircraft cabin. Although the causes are many, two predominate: alcohol abuse in flight and passenger frustration with the entire flying experience.

### Hypoxia

As the aircraft ascends, the environment in the passenger cabin adjusts for the lower air pressure outside but, in general, maintains an altitude-equivalent pressure that does not exceed 8000 ft. With the adjustment in pressure from sea level to cabin altitude the available oxygen in the air is reduced as previously discussed. Fortunately the physiology of healthy individuals also adjusts and compensates as oxygen levels drop from an arterial blood saturation of 98% to 92%. Even in the comfort of the airliner’s cabin there can be a slight diminished dark adaptation and color sensitivity with vision accompanied by increased cardiac output due to increasing rate and volume output. The respiratory system adjusts with increased pulmonary ventilation by both rate and volume increase. Cognitive function symptoms have been reported and include drowsiness, inattentiveness, and concentration difficulty (12, 19).

### Deep Vein Thrombosis

The lay press has added to the lexicon with the introduction of the phrase “economy class syndrome.” In reality, thrombosis is not solely a manifestation of cramped seating in coach class but has been reported in passengers who fly business and first class as well as in those who sit for long periods in buses, cars, theaters, and at work. In a recent review of the 1990s, published by Kesteven & Robinson, at least 200 cases of thrombosis related to travel were reported (14). When the annual incidence of deep vein thrombosis (DVT) is considered in a general European population the rate is between 1.6 and 1.8 per thousand (3).

Some members of the traveling public have a genetic tendency for increased clotting that has been estimated to have a prevalence as high as 20% in the general population. Other preexisting factors such as illness, smoking, and medication may represent preexisting risk factors leading to DVT during or following traveling. A review of the medical literature fails to find significant epidemiological studies that demonstrate a statistical significant increase in DVT as a result of traveling by any means in the absence of preexisting risk factors. In the absence of any good prospective published studies, the evidence linking DVT with flying is circumstantial (3).

Risk factors for the development of DVT include the following (3):

- Blood disorders affecting clotting tendency
- Impairment of blood clotting mechanism, such as clotting factor abnormality
- Cardiovascular disease
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- Current or history of malignancy
- Recent major surgery
- Recent trauma to lower limbs or abdomen
- Personal or family history of DVT
- Pregnancy
- Estrogen hormone therapy, including oral contraceptives
- Increasing age above 40 years
- Prolonged immobilization
- Depletion of body fluids causing increased blood viscosity (Note that this is not dehydration as a result of dry aircraft cabin air)
- Tobacco abuse
- Obesity
- Varicose veins

To investigate this issue Dr. Barry Jacobson and his colleagues studied cockpit crews who were flying commercial airlines from Johannesburg, South Africa. The participants completed detailed questionnaires and agreed to blood sampling. No flight was less than three hours sitting in the cockpit. The aircrews were screened for thrombotic events using fibrin breakdown products. These crewmembers were exposed to altitude changes approximating 5000 ft altitude initially to cabin altitudes of approximately 7000 ft. Blood samples from the 27 cockpit crewmembers failed to demonstrate any parameters that would suggest thrombotic activity (10).

The two hematological investigators, Kesteven and Robinson, undertook a further study of all symptomatic cases of venous thrombosis presenting at their hospital in the United Kingdom. Over a two-year period there were 1250 cases of DVT with 3.8% of these patients making a journey of greater than 100 miles within four weeks prior to the diagnosis. Among the travelers 60% indicated they had traveled by air, 36% by road, and 4% by rail. A minimum of one medical risk factor for thrombosis was present in all but three of these travelers. Of the travelers, nearly all had developed symptoms within three days of the travel event (81%) and nearly half had symptoms during or within twelve hours of the trip. From the experience of the authors, the incidence of DVT among these travelers in this United Kingdom community approximates 1 per 30,000 (13).

In March 2001, medical experts, airline representatives, and regulatory authorities met to consider gaps in the current knowledge of DVT and air travel. Recommended studies will include the basic science of understanding the pathophysiological parameters of thrombosis, as it may relate to air travel, and an epidemiological study of 200,000 air travelers who are followed for a month to establish the incidence of thrombosis. Finally a large clinical study is to be performed to assess various preventive strategies such as compression stockings, anticoagulating medications, and exercise. The final report will unfortunately not be presented until 2006 (R. Prakash, personal communication).
The Air Transport Medicine Committee of the Aerospace Medical Association in 2001 recommended that passengers with no identifiable risk factors carry out frequent and regular stretching exercises particularly of the lower limbs during flight. Opportunities should be sought to change position in the seat as well as to walk about the cabin. However, this introduces a new risk of being unrestrained during unexpected air turbulence. For those with more identifiable risk factors it is recommended that the traveler seek advice from his or her personal physician.

Circadian Dysrhythmia
Jet lag or, more appropriate, circadian dysrhythmia is a disruption of the normal physiological rhythm of the human body based on a 24-h cycle. This disruption is inevitable for travelers crossing multiple time zones. Circadian rhythm is a synchronized process affecting many physiological functions that establishes a body clock. When traveling across time zones, circadian rhythm is not in synchronization with the new local time nor are physiological functions synchronized to each other. Typically a flight originating on the east coast will depart in the evening and arrive in Europe in mid morning after crossing six time zones. Not only is the airline passenger fatigued owing to the loss of satisfying sleep, but also he has lost six hours off the clock with the potential for a nearly full day of work awaiting.

Westward travel tends to extend the day and, in general, is more readily tolerated, and the body clock readjusts itself more quickly than for eastward travel crossing the same number of time zones. Whichever direction the passenger is traveling, adapting as quickly as possible to the time zone of the new location is recommended. For example, when traveling from the east coast to Europe a two-hour nap after arriving provides an opportunity for rest without deep sleep; then engage the social and business activities for the remainder of the day, going to bed for the night at the usual time by the local clock.

Frequent international travelers will begin to plan for their long flight several days in advance of departure by adjusting the time of their meals and sleep schedule. Alcohol, because of its disruption of normal sleep patterns and, in some, its ability to generate sleep apnea, should not be used as a hypnotic. Short-term hypnotic medications with minimal side effects are available, and this option should be discussed with the traveler’s personal physician (17a). More recently the use of melatonin has been recommended in the lay press as an aid in overcoming jet lag. Research has not been as enthusiastic, nor supportive of the success attributed by promoters (5).

Motion Sickness
In the magazine pocket of the seat in front of most passengers is a small, folded plastic sack for passengers to use if they feel sick. The pilot and ground controllers are interested in a safe, comfortable flight for the passenger. However, flying in weather cannot always be avoided. In rough air the rapid movement of the aircraft about its pitch, roll, and yaw axes stimulates the vestibular and proprioceptive
sensors of the body creating conflicting neurological signals that produces air or motion sickness.

Motion sickness has been defined as a state of diminished health characterized by symptoms that are generated in response to unaccustomed conditions existing in one’s motional environment. The symptoms are progressive from lethargy, apathy, stomach awareness, nausea, pallor, cold sweats, ending in vomiting, and finally total prostration. Fortunately such a progression of symptoms is rare in today’s passenger aircraft.

The incidence of motion sickness can be reduced by the traveler reclining the seat and stabilizing the head against the headrest with eyes closed. This will help reduce the stimulation of the vestibular system as well as the visual stimulation due to the rapid movement of light about the cabin in response to changing aircraft position (18a).

For travelers with a predilection to motion sickness, prophylactic medications are frequently available. Medications as safe as Dramamine or other antihistamines to combinations of scopolamine and dextroamphetamine may be available over the counter or by prescription from the traveler’s physician.

MEDICAL CONTRAINDICATIONS TO FLIGHT

For the reasons described earlier in this chapter, sitting relaxed in an airline cabin at 35,000 ft, traveling 500 miles per hour is not the same as sitting at home in Destin, Florida in an easy chair watching television. The airline passenger will experience some degree of hypoxemia because of the lower partial pressure of oxygen at cabin altitude.

Cardiovascular Conditions

Travelers with unstable congestive heart failure, unstable angina pectoris, or recent recipients of coronary artery bypass graft or transluminal coronary angioplasty have conditions that make them unsuitable for flight. Because of preexisting cardiovascular disease the modest reduction in partial pressure $O_2$ in the cabin can be readily reflected as a modest drop of oxygen in the circulation $P_{aO_2}$. The physiological response to the mild hypoxic state may prove to be fatal.

The potential traveler planning to fly with structural heart disease, coronary artery disease, or recent myocardial infarction should receive clearance from the personal physician. Travelers who experience an acute myocardial infarction (MI) away from home are anxious to return. Roby, in his study of patients with recent MI, found that most patients can travel by air two weeks post-MI if they are stable, not overtaxed by pre- and postflight activities and do not require either a medical escort nor onboard oxygen (23). However, Gray questions the data cited above and suggests that the guidelines of the Aerospace Medical Association be followed provided risks for cardiac output, ongoing ischemia, and arrhythmias are considered (2, 9). For recent angiography a delay of several days would be prudent,
and if there has been thoracic surgery, fourteen days post-op is reasonable (16). The lower atmospheric pressure in the cabin for an individual who has recently undergone chest surgery could result in a 25% expansion of any residual trapped gas in the cavity with compromise to both circulation and respiration. Unfortunately the outcome could lead to a cascade of events with a fatal outcome.

Pulmonary Conditions

Passengers with mild chronic obstructive pulmonary disease (COPD), provided they are symptom-free with normal activities of daily living, are not expected to have difficulty at cabin altitude. However, the hypoxemia, although mild in the cabin of a passenger airliner, can add further stress to a compromised oxygen transport system. For example, if the Pao2 is over 70 mmHg measured in room air, the passenger can most probably tolerate the cabin altitude up to 8000 ft (22). For the more severe COPD passenger with levels below 70 mmHg, inflight medical oxygen must be considered. This will require coordination with the airline’s medical department.

Some physicians have mistakenly advised passengers with bronchial asthma that it should be safe to fly because the cabin air at altitude will be relatively free of pollen and chemical irritants. As mentioned earlier, this is not an appropriate assumption because cabin air is not pristine and may very well carry irritant material. Further, for many patients with asthma, emotional or physical stress can incite an asthmatic attack. Asthmatic passengers are advised to carry medication inflight particularly if they are using inhalers. Oral steroids may be appropriate in preparation for travel (22). Those patients with frequent and poorly controlled asthmatic attacks should avoid air travel.

Neuropsychiatric Conditions

Both the stress related to transiting a busy air terminal and the physiological alterations in an airliner might trigger a personality disorder or psychiatric decompensation in a susceptible passenger. At the very least this may result in disruptions in the passenger compartment or such a serious “break with reality” that physical restraint would be required. The treating physician must understand the realities of potential injury to the patient, passengers, or crewmembers should a psychiatric break occur in the confines of the cabin. A patient who has the potential for acting out, aggressive behavior, noncompliance with medication, or who represents a hazard in stress-provoking social situations should avoid commercial flying. If air travel is necessary there must be confidence that the medication regimen will be maintained and alcohol, as well as illicit drugs, avoided. It may be necessary that the individual have a travel companion who can assist in stress avoidance and management. If consideration is being given for anxiolytics, a therapeutic trial should precede flight to avoid idiosyncratic reactions.

The airline medical department will provide advice on management issues related to the ill traveler. Transportation support is readily available in most airports...
from the front entrance through to the gate and on to the aircraft. Although oxygen support may be required by the passenger, personal tanks of oxygen are not permitted on the aircraft but can be supplied with advance notice by the airline. Seats near the lavatory may be prescheduled. Even seat reconfiguration can be arranged in advance to accommodate a litter; however, this usually requires the patient to purchase tickets for the number of seats required. This may be expensive as at times up to six seats may be required in the first class cabin.

ON-BOARD HEALTH EVENTS

In 1998 the United States Congress directed the Department of Transportation to record deaths occurring on flights aboard U.S. aircraft for the period July 1998 through July 1999. Although every cause of death was not known, a total of 43 deaths were reported. Other published data suggests that the incidence of inflight deaths from medical conditions is between 0.3 to 1 per 1,000,000 passengers. There is no comprehensive database that accurately reflects the frequency of inflight medical events. The Aerospace Medical Association surveyed its physician members asking, in their experience, the (a) frequency that they had been requested on a commercial flight to assist a passenger and (b) what was the presumptive diagnosis. Eight-hundred physicians responded, two thirds indicating they had treated a passenger on at least one occasion, and the total of reported medical events was approximately 1200 with over 600 considered serious. Table 1 provides a listing of those events considered serious. In summary it becomes evident that medical incidences are uncommon, and serious illnesses or death aboard an aircraft are relatively rare. To place these incidences in perspective, over 600 million travelers board U.S. airline carriers each year. Further, flight diversion to an unintended airport for medical reasons remains rare. For example, American Airlines experienced 112 diversions in 1994, and none of the ill patients had previously contacted the airline’s medical department; thus no aircraft personnel were aware of the illness so that special medical needs could be met. Another approach to looking at medical diversions is by revenue passenger miles. In 1995 American Airlines reported 1.52 medical diversions for each billion revenue passenger miles, whereas Air Canada reported a rate of 0.90. Among the causes for medical diversion, cardiovascular events are the most common.

On-Board Emergency Medical Kits

In a marketing survey conducted by American Airlines, at least one physician was a passenger on 85% of all its flights. However, until 1997, when the Federal Aviation Administration (FAA) established the minimum standard contents for an on-board medical kit, all that was available to a physician or other health professional was a simple first aid kit. The minimum FAA medical kit requirements include oropharyngeal airway, blood pressure cuff, antiseptic wipes, tourniquet, a stethoscope, sterile gloves, dextrose, hypodermic needle and syringes, diphenhydramine,
TABLE 1  Serious reported inflight illness (21)

<table>
<thead>
<tr>
<th>Inflight presumptive diagnosis</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Syncope/loss of consciousness</td>
<td>111</td>
</tr>
<tr>
<td>Suspected myocardial infarction</td>
<td>92</td>
</tr>
<tr>
<td>Seizure</td>
<td>61</td>
</tr>
<tr>
<td>Angina</td>
<td>52</td>
</tr>
<tr>
<td>Chest pain</td>
<td>47</td>
</tr>
<tr>
<td>Asthma</td>
<td>42</td>
</tr>
<tr>
<td>Hypoglycemia</td>
<td>31</td>
</tr>
<tr>
<td>Alcoholism</td>
<td>22</td>
</tr>
<tr>
<td>Hysteria/panic</td>
<td>17</td>
</tr>
<tr>
<td>Congestive heart failure</td>
<td>16</td>
</tr>
<tr>
<td>Renal/ureteral stone</td>
<td>15</td>
</tr>
<tr>
<td>Allergic reaction</td>
<td>14</td>
</tr>
<tr>
<td>Chronic obstructive pulmonary disease</td>
<td>14</td>
</tr>
<tr>
<td>Cardiac arrest</td>
<td>14</td>
</tr>
<tr>
<td>Cerebrovascular accident</td>
<td>9</td>
</tr>
<tr>
<td>Drug overdose</td>
<td>8</td>
</tr>
<tr>
<td>Pregnancy (3 deliveries, 4 abortions)</td>
<td>7</td>
</tr>
<tr>
<td>Appendicitis</td>
<td>7</td>
</tr>
<tr>
<td>Urinary obstruction</td>
<td>7</td>
</tr>
<tr>
<td>Cholecystitis</td>
<td>5</td>
</tr>
<tr>
<td>Gastrointestinal bleeding</td>
<td>5</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>26</td>
</tr>
<tr>
<td>Total</td>
<td>622</td>
</tr>
</tbody>
</table>

nitroglycerin, and ephedrine (2). Airlines are free to expand the kit based on their own experience. International airlines such as Air Canada and Qantas carry markedly enhanced medical kits, in part, because of their long over-water flights. In 1991, Qantas was the first airline to introduce automatic external defibrillators (AEDs). In a five-year period following the introduction of AEDs there were 27 episodes of inflight cardiac arrest of which six passengers were in ventricular fibrillation. Two of these six were successfully resuscitated. These cardiac events occurred among the approximately 31,000,000 passengers flown by Qantas during that period (22).

American Airlines was the first U.S. carrier to initiate a program on its fleet of enhanced medical kits including AEDs. The airline recognized, though, that there was no economic advantage to putting defibrillators on board flights. Not only was the cost significant, but 20,000 flight attendants required training (16).
The passage of the Aviation Assistance Act (AAA) in 1998 significantly expanded the liability protection for physicians who respond to on-board medical incidences. The purpose of this federal legislation was to remove a significant impediment to physicians responding to an on-board call for assistance. The AAA states in part: "An individual should not be liable for damages in any action brought in a federal or state court arising out of the acts or omission of the individual in attempting to provide assistance in the case of an inflight emergency unless the individual, while rendering such assistance, is guilty of gross negligence or willful misconduct" (7b).

American Airlines initially placed AEDs on all over-water-equipped aircraft and activated the system on July 1, 1997. Their four-year experience through June 2001 identified 545 AEDs available on aircraft at which time there were 45 events requiring shock. There were 21 saves and 24 who failed to respond; survival rate was 50% for the immediate event and follow up was 34% (15 people) who were still alive (16).

In 2001 the Air Transport Medicine Committee of the Aerospace Medical Association updated its 1998 recommendation for on-board emergency medical kits for commercial airlines (1). The contents of the recommended kit are listed in Table 2.

Inflight Telemedicine

Commercial aircraft are equipped with excellent telecommunications capabilities. Some airlines have the capability to downlink electrocardiograph tracings and vital signs. A number of airlines with large medical departments maintain a doctor availability to the cockpit 24 hours a day to provide real time advice in the event of an on-board medical emergency. This “physician-on-call” program has reduced the need for medical diversion (7). Other airlines use a company that links emergency room physicians to the airline in real time to provide remote medical consultation. With new airliners that are projected to carry up to 1000 passengers, within the decade, it is anticipated that real time video will be available to the on-ground medical consultant.

THE AIRLINER AS A VECTOR OF DISEASE

Although passengers are crowded into a relatively small cubic volume, the aircraft’s air conditioning and ventilation system is able to maintain a low bacteria and fungi count in the cabin. This is enhanced by the use of maximum efficiency HEPA filters that are successful in screening out 99.97% of the microorganisms as small as 0.3 µg. Although viruses are smaller many become trapped in the filter as their mode of dissemination is by forming clumps or riding dust particles that are much larger. Wick & Irvine conducted a study that found lower counts of bacteria and mold in passenger aircraft than in city buses, shopping malls, and in the outside air at city street corners (28). Other studies have found that the concentrations of biological agents were lower in airliners as compared with other
TABLE 2  Emergency medical kit (1)

<table>
<thead>
<tr>
<th>Medication</th>
<th>Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Without defibrillator/monitor or monitor</td>
<td></td>
</tr>
<tr>
<td>Epinephrine 1:1000</td>
<td>Stethoscope</td>
</tr>
<tr>
<td>Antihistamine</td>
<td>Sphygmomanometer (electronic preferred)</td>
</tr>
<tr>
<td>Dextrose 50% inj. 50 ml</td>
<td>Airways, oropharyngeal (3 sizes)</td>
</tr>
<tr>
<td>Nitroglycerin tab. or spray</td>
<td>Syringes (appropriate range of sizes)</td>
</tr>
<tr>
<td>Major analgesic inj.</td>
<td>Needles (appropriate range of sizes)</td>
</tr>
<tr>
<td>Moderate analgesic p.o.</td>
<td>IV catheters (appropriate range of sizes)</td>
</tr>
<tr>
<td>Sedative anticonvulsivant (inj)</td>
<td>Antiseptic wipes</td>
</tr>
<tr>
<td>Anti-emetic inj.</td>
<td>Gloves (disposable)</td>
</tr>
<tr>
<td>Bronchial dilator inhaler</td>
<td>Needle disposal box</td>
</tr>
<tr>
<td>Atropine inj.</td>
<td>Urinary catheter</td>
</tr>
<tr>
<td>Adrenocortical steroid inj.</td>
<td>IV admin. set</td>
</tr>
<tr>
<td>Diuretic inj.</td>
<td>Venous tourniquet</td>
</tr>
<tr>
<td>Oxytocin inj.</td>
<td>Sponge gauze (4 × 4)</td>
</tr>
<tr>
<td>Sodium chloride 0.9%</td>
<td>Tape adhesive</td>
</tr>
<tr>
<td>ASA p.o.</td>
<td>Surgical mask</td>
</tr>
<tr>
<td></td>
<td>Flashlight and batteries</td>
</tr>
<tr>
<td></td>
<td>Blood glucose strips</td>
</tr>
<tr>
<td></td>
<td>Emergency tracheal catheter (or large gauge IV cannula)</td>
</tr>
<tr>
<td></td>
<td>Cord clamp</td>
</tr>
<tr>
<td></td>
<td>BLS cards</td>
</tr>
<tr>
<td></td>
<td>Bag-valve mask</td>
</tr>
<tr>
<td></td>
<td>A list of contents</td>
</tr>
<tr>
<td>2. With defibrillator/monitor alone</td>
<td></td>
</tr>
<tr>
<td>Same list 1, adding</td>
<td>ACLS cards</td>
</tr>
<tr>
<td>Lidocaine</td>
<td></td>
</tr>
<tr>
<td>Epinephrine 1:10,000</td>
<td></td>
</tr>
</tbody>
</table>

transportation modes, the outdoor air, and even residential environments (26). In considering microbe transmission in an aircraft cabin the reader is reminded that the air circulation is laminar, that is side to side, and enters the cabin from overhead distribution outlets and leaves along both side walls of the cabin at near floor level. Thus there is little air exchange fore to aft but along the seat row. However, transmission of infectious disease has occurred among aircraft passengers.

In the two-year time frame, 1992 to 1994, the Centers for Disease Control and Prevention (CDC), with other health agencies, conducted seven tuberculosis investigations of a crewmember and six passengers in separate events with active disease. There was legitimate concern that the closed aircraft cabin environment could enhance the transmission of airborne pathogens such as *M. tuberculosis*. These investigations focused on the potential exposure of more than 2600 passengers and crew on 191 flights involving a wide series of different type aircraft (27).
The index patient in each investigation was considered highly infectious and, in one case, the patient had biopsy- and culture-confirmed laryngeal tuberculosis, its most infectious form. Two index patients had multi-resistant tuberculosis. Of the seven investigations, only two produced evidence suggestive of possible transmission of a tuberculosis infection. These investigations suggest that air travel does not carry a greater risk of transmission than other activities that bring an index case into contact with others.

In a separate incident, an airline pilot with active TB reportedly flew over a six-month period with 48 other pilots. All contacts were investigated, and there were no skin test conversions and no radiological changes (18). In the late 1990s the World Health Organization (WHO) established an expert panel to review the potential for tuberculosis transmission among passengers in commercial airliners. The panel published a report that included ten recommendations for the traveler, the physician, and the airline company (See Reference 29 for the complete list).

Influenza is considered highly contagious and provides the background for the scenario of an exposure event that occurred in 1977 (17). A young woman who became the index case developed acute respiratory symptoms just 15 min after boarding an Alaskan flight. There then followed an experience that frequent flyers know all too well when the flight was delayed because of mechanical difficulties leaving most of the passengers on the aircraft for over three hours. The close proximity of passengers, a nonoperating ventilation system, and low humidity contributed to a high attack rate of influenza. Of the 53 passengers and crew on board the aircraft who were interviewed, 38 reported that they had developed the flu, and one week later there was a secondary attack rate of 20% among household contact of these passengers. This cluster of ill patients was identified because most were treated by a single physician who recognized the epidemic and reported it to health officials. The risk of infection was significantly increased by the unique circumstances associated with the maintenance delay of the flight. The WHO panel discussed above recommended that in case of ground delays of more than 30 min, adequate ventilation must be supplied on board.

The first sanitary convention for aerial navigation was conducted in 1933 and recognized the importance of aviation to the worldwide community. A number of issues were discussed and included infectious disease control, aircraft disinfection, and medical inspection. One of the focused concerns was control of the yellow fever mosquito vector. Following World War II, the WHO Committee on Hygiene and Sanitation in Aviation became activated and published the “Guides to Hygiene and Sanitation in Aviation.” The most recent guide is dated 1977. Over the last half-century, vectors for yellow fever, malaria, and dengue have been identified on aircraft. The term airport malaria refers to cases of malaria near international airports among people who have not recently traveled into endemic areas. In the past 30 years most European countries, the United States, Israel, and Australia have experienced confirmed or probable cases of airport malaria. In those 30 years the United States has reported four such cases.
Both the Advisory Group for Aerospace Research and Development and WHO recommend aircraft disinsection because there is adequate evidence that disease vectors, particularly mosquitoes, are being imported into countries on aircraft (8). WHO recommends one of three ways to disinsect an aircraft whether carrying cargo or passengers.

1. Blocks away disinsection: Once the cabin is closed and the aircraft taxied from the terminal but not yet airborne, an aerosol spray of insecticide is applied.

2. Preflight and top-of-descent disinsection: Aerosol insecticides are applied while the aircraft is still on the ground and while passengers are boarding. This permits closed compartments to be opened and sprayed with permethrin. In addition a quick-acting insecticide is applied at the time of descent.

3. Residual disinsection: a residual or long-acting insecticide is applied to the internal surfaces of the aircraft except in the food preparation area. Spot applications are made to surfaces that are frequently cleaned.

Such procedures are often helpful in reducing agricultural or forestry pests such as the Mediterranean fruit fly. Aircraft disinsection is not without its detractors as the need for disinsection is challenged, and concern if not, in fact, emotional anxiety results from the worry about the toxicity of the insecticide (8).

Unfortunately there are other nonpaying passengers aboard aircraft flying international routes: Snakes, spiders, nematodes, fungi, pathological bacteria, and beetles may have a free ride to oblivion or the Garden of Eden. Many of these unwanted passengers will not find an environment conducive to their survival, but unfortunately some will.

THE ENVIRONMENTAL IMPACT OF FLIGHT

Noise

In the early years of the jet engine, people who were living around airports described the engine as a device for converting fuel into noise. Unfortunately noise is a fundamental characteristic of aircraft operations. Without attempting to describe the physics or characteristics of noise it has generally been considered to be an unacceptable sound. Airport noise has been described as interfering with speech, creating irritability, disrupting sleep, frightening children, and disrupting social intercourse. Clyde Thibeault, in his chapter “The Impact of the Aerospace Industry on Environment and Public Health” in Fundamentals of Aerospace Medicine, summarizes some of the nonauditory health effects suggested to be caused by aircraft noise: increase in mortality rates, decreased quality of life, elevated blood pressure, elevated levels of stress hormones, increased incidence of cardiovascular effects, increase in incidence of birth defects and low birth weight babies, and increase in minor psychological symptoms (27).
The International Civil Aviation Organization became involved when noise near airports became a significant concern. A series of recommendations were generated that required participation of aircraft operators, manufacturers, airport operators, governments, and citizens to obtain noise relief. Although there have been numerous successes, government authorities at all levels continue to address the problem. In the United States there have been active programs to remove homes and communication-sensitive institutions and businesses such as schools from the near vicinity of airports and major flight paths. The Environmental Protection Agency monitors noise levels and neighborhood impact studies to assess airport noise. Airline operators may be required to reduce power after takeoff or to follow unconventional flight patterns and to establish time restrictions on flight operations to reduce the environmental impact. An example of such control of flight operations occurs at Reagan National Airport with operational time constraints, a flight pattern that parallels the Potomac River, and takeoff requirements that reduce power shortly after becoming airborne.

One form of aviation noise that has had a significant impact on aircraft development is the supersonic flight generation of the sonic boom. The British and French Concorde is the only commercial aircraft that flies at supersonic speeds but primarily only over water. With the generation of sonic booms, studies conducted in the late 1960s and early 1970s measured the societal impact of supersonic flights over the United States. The startle effect was not acceptable to the American public and made an impact on the decision to discontinue further development of the United States’ Supersonic Transport (SST).

It is recognized that the Department of Defense has operational requirements for training and operations where supersonic booms are generated. However, this high-speed flight activity primarily takes place in airspace over thinly populated areas.

OZONE

Another concern that derailed the development of a United States Super Sonic Transport (SST) was the possibility that a fleet of aircraft flying above 50,000 ft could deplete the ozone that is distributed in the stratosphere. The significant disruption of the ozone layer over Antarctica is not believed to be attributable to the aviation industry, however. In the 1970s there was concern that NO\textsubscript{x} from stratospheric aircraft would interact with ozone and result in its depletion. Science has now demonstrated that aircraft emissions actually increase ozone in the upper atmosphere. The NO\textsubscript{x} emissions from subsonic aircraft are estimated to have increased ozone concentration at cruise altitudes in the northern mid latitudes by upwards of 6% (27). However, there continue to be numerous uncertainties associated with the atmospheric ozone levels projected into the future. Not surprising, continued study is needed of the potential impact of the aerospace industry on ozone with related changes in climate and eventually the health of the population.
Although this chapter has focused on concerns for the health of passengers and
the potential adverse impact on the public’s health, the positive benefits of aviation
to the world far exceed the disadvantages. The societal benefits of diversity of race
and culture would not have achieved its magnitude without the rapid international
travel provided by aviation. World commerce is the beneficiary of transport of
people and product; the ease of travel has played an invaluable role in international
relations. The ability to respond almost instantaneously to a calamity anywhere in
the world is due to international aviation. The benefits are so real, so evident, and
in such demand that commercial air travel will continue to grow to the benefit of
humankind.

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