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Managing passengers with stable respiratory disease planning air travel: British Thoracic Society recommendations

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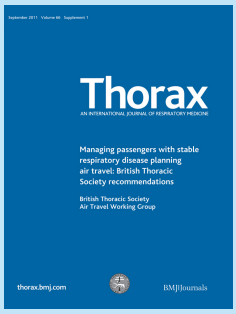

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Managing passengers with stable respiratory disease planning air travel: British Thoracic Society recommendations

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INTRODUCTION

Need for new recommendations for managing passengers with respiratory disease planning air travel

Since the first British Thoracic Society (BTS) recommendations published in 2002[1] and web update in 2004,[2] data from several studies have confirmed previous findings suggesting that neither resting sea level oxygen saturations nor forced expiratory volume in 1 s (FEV_1) reliably predict hypoxaemia or complications of air travel in passengers with respiratory disease.[3–7] It is thus now clear that there is no reliable threshold in these variables to determine accurately the safety of air travel or need for in-flight oxygen in an individual patient. Nevertheless, the need for practical recommendations remains. The new guidance covers bronchiectasis, cancer, hyperventilation and dysfunctional breathing, obesity, pulmonary arteriovenous malformations and sinus and middle ear disease, and has expanded sections on infection and comorbidity with cardiac disease.

UK airports handled over 235 million passengers in 2008[8] and around 2 billion passengers flew in 2006, 760 million worldwide.[9] The average age of passengers is likely to rise, making comorbidity more likely. Over 30 years ago around 5% of commercial airline passengers were thought to have a pre-existing medical condition.[10] With new ultra-long haul flights, passengers are exposed to cabin altitudes of up to 8000 ft for up to and sometimes more than 20 h. Longer journeys increase the odds of in-flight medical incidents, and physiological disturbances associated with moderate but prolonged hypoxia, prolonged immobility and protracted exposure to reduced barometric pressure are unknown. Longer flights may increase the risk of desaturation, perhaps reflecting a gradual fall in cabin oxygen pressure.[11]

There are no established methods for quantifying in-flight medical emergencies.[12] A North American service offering radio link assistance for in-flight medical emergencies logs over 17 000 calls a year; respiratory events accounted for 10–12% of such calls from 2004 to 2008, the third most frequent diagnostic category (Dr Paulo Alves, MedAire Inc, personal communication, 2009). Respiratory symptoms were also the third most frequent cause of medical diversion. Physicians must therefore be aware of the potential effects of the flight environment in those with lung disease. We hope that greater awareness of the challenges posed by air travel will allow physicians to encourage patients to fly safely wherever possible.

A UK-wide survey of respiratory physicians in 1997 indicated that many would welcome advice on assessing patients' fitness to fly.[13] Other information sources include British and European,[14–16] North American and Canadian[17 18] guidelines on chronic obstructive pulmonary disease (COPD), a British aviation medicine textbook,[19] *Aviation, Space and Environmental Medicine* journal supplements[20–22] and air travel publications.[23] These are, however, not always readily available and not all provide consistent, practical or comprehensive coverage.

As in 2002 and 2004, the 2011 recommendations are an expert consensus view based on literature reviews and have as their main aim to give practical advice for respiratory specialists in secondary care. We hope that they will also provide a valuable reference for practice and specialist respiratory nurses, medical and nursing staff in emergency departments and ambulance staff who may be asked for advice at airports. Information for general practitioners and patients is available at http://www.brit-thoracic.org.uk/. An expanded and comprehensive background literature review has been retained as a resource for educational, reference and research purposes.

The advice applies to commercial flights only (including scheduled repatriation with a medical or nurse escort) and excludes emergency aeromedical evacuations. However, if medical practitioners do assist at an in-flight medical emergency, most airlines will indemnify them, the aircraft will have medical equipment and they can often access specialist advice from ground-based support companies.

Purpose of recommendations

Our aim is to:

1. Enhance safety for passengers with lung disease travelling on commercial flights and reduce respiratory complications.
2. Promote further understanding among healthcare professionals that patients with respiratory

disease may require clinical assessment and advice before air travel.
3. Provide an authoritative up-to-date literature review of the latest available evidence.
4. Provide consistent, practical and comprehensive advice for healthcare professionals managing these patients.
5. Formulate key research questions to provoke further investigation. This in turn will help generate a strengthened high-quality evidence base from which clearer evidence-based guidelines can be proposed.
6. Promote development of methods for monitoring the size of the problem.

Methods of production

The Air Travel Working Party defined the remit of the recommendations. Independent literature searches were performed by Working Party members and individual draft sections prepared, using where relevant the 2002 and 2004 documents as a starting point. The search strategy is given in Appendix 1 in the online supplement. From these draft sections a draft document was generated summarising the current evidence and containing recommendations regarding (1) the flight environment; (2) physiological effects of exposure to altitude; (3) clinical assessment; (4) respiratory disorders presenting a possible risk for potential air travellers; and (5) oxygen supplementation. The document was reviewed by the Working Party and redrafted before presentation at an Open Meeting at the 2009 BTS Winter Meeting. It was circulated to the BTS Standards of Care Committee and reviewers (see Appendix 2). A draft was available for public consultation on the BTS website in January/February 2010. A final draft was produced incorporating feedback after discussion and further review by the BTS Standards of Care Committee. Following review of the available literature, the revised SIGN grading system (see Appendix 3) was used to grade recommendations for each section.

SUMMARY OF KEY POINTS AND RECOMMENDATIONS

The flight environment and effects of altitude

- Commercial aircraft are pressurised to cabin altitudes of up to 8000 ft (2438 m) although this ceiling may be exceeded in emergencies. Cabin altitudes in the Boeing 787 Dreamliner are likely to remain below 6000 ft (1829 m). At 8000 ft (2438 m) the partial pressure of oxygen falls to the equivalent of breathing 15.1% oxygen at sea level. In healthy passengers arterial oxygen tension (Pa_{O_2}) at 8000 ft (2438 m) is influenced by age and minute ventilation, but falls to between 8.0 and 10 kPa (60–75 mm Hg, oxygen saturation measured by pulse oximetry (Sp_{O_2}) 89–94%); when exercising or sleeping it may be lower. Altitude exposure may worsen hypoxaemia in pulmonary disease. The physiological compensation for acute hypoxaemia is mild to moderate hyperventilation, limited by the fall in arterial carbon dioxide tension (Pa_{CO_2}), and a moderate tachycardia.
- FEV_1 and Sp_{O_2} are useful markers of clinical severity. However, neither resting sea level oxygen saturations nor FEV_1 appear to predict hypoxaemia or complications accurately during or after air travel in patients with respiratory disease.[3–7] Further research is required to determine whether a symptom-based approach, for instance the MRC dyspnoea scale,[24] or exercise testing might be more reliable for screening.
- Healthcare professionals are often asked for advice and we suggest a practical approach to patients at increased risk of hypoxaemia or other complications of air travel. Physicians should consider the patient's previous flight experience, flight duration, destination and, if relevant, the time since the last exacerbation of their chronic condition. Generic patient advice is given below (a patient information leaflet is available at http://www.brit-thoracic.org/), and further evaluation should be carried out in those likely to be at greatest risk (see categories below) or about whom the physician is concerned. The patient's usual care such as bronchodilator therapy should be optimised before air travel. Patients should understand that the hypoxic challenge test (HCT) is not a 'fitness to fly' test but is used to determine whether a patient needs in-flight oxygen and that, even with in-flight oxygen and/or ventilator support, safety cannot be guaranteed.
- Complex patients can be referred for testing in a hypobaric chamber (see Appendix 4). While air travel is almost always possible with appropriate medical support, logistics and economic costs may outweigh the benefits.
- The specialist respiratory physician or paediatrician should be the central referral point for consideration of safety to fly in all cases. Ultimately it should be made clear that the patient takes responsibility for deciding to fly, and that the airline can refuse carriage if the passenger's safety is in doubt.

Patient information

Advance planning is essential. Patients and/or their carer(s) are advised to:

- Book extra services required with the airline in advance such as in-flight oxygen or wheelchairs, and formalise any agreement to take on board nebulisers, ventilators or continuous positive airway pressure (CPAP) machines. Airlines may charge for such services; information is available from the Grown-Up Congenital Heart Patients Association (http://www.guch.org.uk/), Pulmonary Hypertension Association (http://www.phassociation.org/) and the US National Home Oxygen Patients Association (http://www.homeoxygen.org/).
- Arrange medical insurance. If medical insurance is declined and/or patients travel without, they should be aware of the costs of emergency treatment and repatriation.
- Ensure an adequate supply of prescription medicines in carry-on and checked baggage. Currently, a doctor's letter is required for liquid medicines exceeding 100 ml taken into the aircraft cabin.
- Obtain a doctor's letter if taking unusual, numerous, trial or controlled medication, syringes and/or needles, or if patients have metallic implants (such as coils inserted during bronchial or pulmonary artery embolisation).
- Ask the physician whether an emergency supply of antibiotics, with or without prednisolone, is required.
- Consider booking an aisle seat near the toilets.
- Keep well-hydrated and mobile, using exercises if not in an aisle seat.
- Avoid or minimise alcohol use and sedatives.

Frequent traveller's medical card (FREMEC)

Patients with medical needs who fly often can obtain a FREMEC which records important medical information and replaces forms otherwise needed for each flight. Once registered, assistance is available whenever the patient flies. FREMEC is issued

by many airlines; its validity period depends on the medical condition. If a patient flies with a different airline, they should confirm its validity with the new airline.

Pre-flight assessment for adults

If there is doubt about the patient's fitness to fly and if there are comorbidities affecting fitness (such as cardiovascular disease or immunosuppressant therapy), assessment is advised. In general the patient should be stable and have recovered from any recent exacerbation before travel. We recommend that those with the following conditions should be assessed with history and examination as a minimum:

- Previous air travel intolerance with significant respiratory symptoms (dyspnoea, chest pain, confusion or syncope).
- Severe COPD (FEV_1 <30% predicted) or asthma.
- Bullous lung disease.
- Severe (vital capacity <1 litre) restrictive disease (including chest wall and respiratory muscle disease), especially with hypoxaemia and/or hypercapnia.
- Cystic fibrosis.
- Comorbidity with conditions worsened by hypoxaemia (cerebrovascular disease, cardiac disease or pulmonary hypertension).
- Pulmonary tuberculosis.
- Within 6 weeks of hospital discharge for acute respiratory illness.
- Recent pneumothorax.
- Risk of or previous venous thromboembolism.
- Pre-existing requirement for oxygen, CPAP or ventilator support.

Contraindications to commercial air travel

- Infectious tuberculosis.
- Ongoing pneumothorax with persistent air leak.
- Major haemoptysis.
- Usual oxygen requirement at sea level at a flow rate exceeding 4 l/min.

Hypoxic challenge testing (HCT)

The hypoxic challenge test (HCT) is used to assess whether patients need in-flight oxygen; further research is needed to determine more precisely its place in assessing respiratory patients before air travel. There is currently no evidence to justify amending earlier advice for patients in whom the respiratory physician considers HCT is required. The HCT is performed in a specialist lung function unit after referral to a respiratory specialist.

The UK Flight Outcomes Study showed that, even in specialist centres, only 10% of patients undergo a walk test as part of a fitness to fly assessment.[6] We have therefore removed the earlier reference to walk tests. The recommended course of action, depending on the HCT result, is shown in table 1. Normal temperature and $Paco_2$ are assumed; results in hyperventilation must be interpreted with caution. Where there is doubt, it seems prudent to err on the side of recommending oxygen.

Table 1 Results of hypoxic challenge test (15% fractional inspired oxygen for 20 min) with revised SIGN grading (see Appendix 3)

Hypoxic challenge test (HCT) result	Recommendation
Pao_2 ≥6.6 kPa (>50 mm Hg) or Spo_2 ≥85%	In-flight oxygen not required (C)
Pao_2 <6.6 kPa (<50 mm Hg) or Spo_2 <85%	In-flight oxygen required at 2 l/min via nasal cannulae (C)

Pao_2, arterial oxygen tension; Spo_2, oxygen saturation.

Pre-flight assessment for infants and children

- For infants born at term (>37 weeks) it is prudent to delay flying for 1 week after birth term (corrected gestational age 40 weeks) to ensure they are healthy (√).
- Infants born prematurely (<37 weeks) with or without a history of respiratory disease who have not yet reached their expected date of delivery do not require HCT, which is unreliable in this group,[25] but should have in-flight oxygen available, delivered at 1–2 l/min if they develop tachypnoea, recession or other signs of respiratory distress) (C).
- Infants under 1 year with a history of neonatal chronic respiratory problems should be discussed with a specialist respiratory paediatrician and HCT performed. Infants with Spo_2 <85% on HCT should have in-flight oxygen available (D); paediatrician discretion should be used for infants with Spo_2 85–90% and, where there is doubt, the doctor should err on the side of caution (√).
- In children with cystic fibrosis (CF) or other chronic lung diseases who are old enough for spirometry and whose FEV_1 is <50% predicted, HCT is recommended. If Spo_2 falls below 90%, in-flight oxygen is advised (C).
- Infants and children who are oxygen-dependent at sea level will need their oxygen flow rate doubled at cruising altitude and should not need HCT (C).
- Infants and children who have had long-term oxygen within the last 6 months should have HCT (D).

Box 1 describes the method for performing HCT in infants or young children. In older children HCT may be performed using a mouthpiece rather than a plethysmograph.

Logistics of travel with oxygen

- Oxygen-dependent patients can fly with adequate precautions.
- Patients may be able to take their own small full cylinders on board if agreed by the airline in advance; patients should check whether their equipment is insured against loss and/or damage.
- If oxygen is required, it is usually supplied by the airline and must be booked in advance. The airline medical department will issue a MEDIF form (see http://www.iata.org/ or Appendix 6 in online supplement) or their own medical form. This is completed by the patient and GP or hospital

Box 1 Hypoxic challenge test (HCT) in infants or young children

The infant or young child, wearing nasal cannulae, is placed in a whole body plethysmograph with a parent or carer and baseline oxygen saturation (Spo_2) is monitored for a few minutes until the reading is stable. The air in the body box is then diluted to 15% oxygen with nitrogen. If Spo_2 falls to <85% (infants <1 year of age) or <90% (older children), supplementary in-flight oxygen is recommended. The flow required is determined by titrating oxygen via the nasal cannulae to restore Spo_2 to the original value. This will usually be 1–2 l/min. Where whole body plethysmography is are not available, a tight-fitting non-rebreathing face mask incorporating a one-way valve assembly may be used through which high-flow 14% oxygen is administered, although this may not be as reliable.

specialist, with details of the patient's condition and oxygen requirements. The airline's Medical Officer or external advisors will then evaluate the patient's needs.
- The airline must be consulted in advance if humidification equipment is required.
- In-flight oxygen is prescribed at a rate of 2 l/min or 4 l/min and should be given by nasal cannulae; it should be used according to the airline's instructions.
- Many airlines now use pulsed dose (breath-activated) systems. Some devices may pose problems for frail, very young (<6 years old) or very small (≤13 kg) passengers who may have irregular or shallow breathing patterns. It is prudent to ensure such patients can activate the system before travelling, or agree an alternative with the airline.
- Lightweight battery-operated portable oxygen concentrators (POCs) are now popular and many airlines allow their use on board. In the USA, legislation specifically allows certain types for use in all phases of flight (http://rgl.faa.gov). Currently, only the AirSep LifeStyle POC and Inogen One POC units are permitted. Enough batteries for the flight and possible delays must be taken, and the airline informed before travel.
- The need for oxygen on the ground and while changing flights must be considered as airlines do not provide oxygen for use at airports. A direct flight is preferable. If connecting flights are unavoidable, separate arrangements must be made for oxygen while on the ground during stopovers. The main oxygen distributors have their own international distribution network and can supply oxygen at intended destinations if active in those areas. A charge is likely for this service. Appendix 5 lists major destinations exceeding 8000 ft (2438m).

Logistics of travel with ventilator support

- Ventilator-dependent patients should consult their ventilation specialist before arranging air travel. The airline will need to know their requirements at the time of reservation and to have a doctor's letter outlining the diagnosis, necessary equipment, recent blood gas results and ventilator settings. A medical escort is needed for fully dependent (intubated) patients, and ventilator specialist advice is essential well in advance. The ventilator may have to be switched off for take-off and landing and the patient ventilated manually; arrangements must be made for proceeding through air terminals before and after the flight.

Disease-specific recommendations with revised SIGN grading (see Appendix 3)

Airways disease (asthma and COPD)

FAA and European regulations mandate inclusion of a bronchodilator inhaler in aircraft emergency kits[26]; regulations for aircraft registered by other regulators vary. A bronchodilator given via a spacer is as effective as a nebuliser.[27] Many airlines permit use of dry cell battery operated nebulisers (except during take-off and landing), but passengers must check in advance.[28] Nebulisers are not included in airline medical kits because aircraft oxygen systems cannot provide the high flow rates needed to ensure correct dose delivery and compressor devices are heavy and bulky.[29]

- For acute exacerbations on board, the patient's own bronchodilator inhaler (or airline emergency kit inhaler if available) should be given, with a spacer if appropriate, and the dose repeated until symptomatic relief is obtained (D).
- Patients with severe or brittle asthma or severe COPD (FEV_1 <30% predicted) should consult their respiratory specialist beforehand and consider taking an emergency supply of prednisolone in their hand luggage as well as supplies of their usual medication (D).

Bronchiectasis

- Nebulised antibiotics or nebulised bronchodilators should not be required (D).

Cancer

- Severe or symptomatic anaemia should be corrected beforehand, as should hyponatraemia, hypokalaemia and hypercalcaemia (D).
- Treatment (radiotherapy, chemotherapy and/or stenting) for major airway obstruction, including upper airways stridor, should be complete before travel and sufficient time passed to enable the physician to confirm stability (D).
- Patients with lymphangitis carcinomatosa or superior vena caval obstruction should only fly if essential, and have in-flight oxygen available (D).
- Pleural effusions should be drained as much as possible before travel (D).
- Patients with major haemoptysis should not fly (D).
- A doctor's letter is required for patients taking controlled drugs, with details of the patient's name, address, date of birth, outward and return dates of travel, countries being visited and drugs carried, including doses and total amounts. The patient or carer should also consult the Home Office to determine local controlled drug importation rules (http://www.homeoffice.gov.uk/) (D).
- Neutropenic patients should be aware of the risk of infection (and its peak timing after chemotherapy) arising from close proximity to other passengers (D).
- Airlines do not allow patients to fly within 24 h of a seizure. The patient or carer should know that medical insurance is likely to be refused if cerebral metastases are present, and that repatriation costs are significant (D).

Cardiac comorbidity

The British Cardiovascular Society recently published guidance for air passengers with cardiovascular disease.[30] However, since cardiac and pulmonary conditions often coexist and respiratory physicians are often consulted about HCT in cardiac patients, we felt it appropriate to retain this section in our current recommendations. Physicians should use their discretion to undertake HCT or recommend in-flight oxygen for patients with coexistent cardiac and pulmonary disease. Where measured haemodynamics or correlates of ventricular function are more severe than symptoms suggest, physician discretion should determine use of in-flight oxygen.

Coronary artery disease

At 8000 ft (2438 m) there is a 5% fall in ischaemic threshold (measured as the product of heart rate and systolic blood pressure at the ECG threshold for ischaemia).[31]

- Patients who have undergone elective percutaneous coronary intervention can fly after 2 days (C).
- Patients at low risk after ST elevation myocardial infarction (STEMI)—namely, restored TIMI grade 3 flow on angiography, age <60, no signs of heart failure, normal ejection fraction and no arrhythmias—can fly after 3 days (C).
- Other patients may travel 10 days after STEMI unless awaiting further investigation or treatment such as revascularisation or device implantation. (C) For those with complications such as arrhythmias or heart failure, advice in the relevant section below should be followed.

- Patients with non-ST elevation myocardial infarction (NSTEMI) should undergo angiography and revascularisation before considering air travel (C).
- Patients who have undergone uncomplicated coronary artery bypass grafting should be able to fly within 14 days but must first have a chest x-ray to exclude pneumothorax (C).
- Patients with stable angina up to Canadian Cardiovascular Society (CCS) functional class III are not expected to develop symptoms during commercial air travel (C).
- Patients with CCS functional class IV symptoms (defined as the inability to carry on any activity without discomfort), who may also get stable angina at rest, should be discouraged from flying. (C) If air travel is essential they should receive in-flight oxygen at 2 l/min and a wheelchair is advisable (C).
- Patients with unstable angina should not fly (D).

Cyanotic congenital heart disease

- Physicians should use their discretion in deciding whether to perform HCT and/or advise in-flight oxygen (√).
- Those in New York Heart Association (NYHA) functional class IV should avoid air travel unless essential. If flying cannot be avoided, they should receive in-flight oxygen at 2 l/min (D).

Heart failure

- Patients who are hypoxaemic at sea level with coexistent lung and/or pulmonary vascular disease should be considered for HCT (D).
- Patients in NYHA functional class I–III (without significant pulmonary hypertension) can fly without oxygen (C).
- Patients with severe disease in NYHA functional class IV should not fly unless essential. If air travel cannot be avoided, they should have in-flight oxygen at 2 l/min (C).

Hypertension

- Patients with severe uncontrolled hypertension should have it controlled before embarking on commercial air travel (D).

Pulmonary hypertension

- Those in NYHA functional class I or II can fly without oxygen (D).
- Those in NYHA functional class III or IV should receive in-flight oxygen (D).

Rhythm disturbance, pacemakers and defibrillators

Modern pacemakers and defibrillators are compatible with aircraft systems.

- Patients with unstable arrhythmias should not fly (C).
- Patients with high-grade premature ventricular contractions (Lown grade ≥4b) should be discouraged from flying, but may fly at the physician's discretion with continuous oxygen at 2 l/min (D).

Valvular disease

- Patients with valvular disease causing functional class IV symptoms, angina or syncope should use in-flight oxygen at 2 l/min if air travel is essential (D).

Hyperventilation and dysfunctional breathing

- Patients with hyperventilation, dysfunctional breathing and/or panic disorder should be assessed beforehand by a specialist in these disorders and breathing modification exercises and/or pharmacotherapy should be started before travel (D).
- Where the cause of breathlessness on board is in doubt, oxygen should be given and skilled medical assistance obtained as soon as possible (D).
- Rebreathing techniques may be used on board for acute hyperventilation (D).
- Evaluation of response to rapidly acting anxiolytics is advised before travel (D)

Airborne infections

- Pre-flight assessment is advised for those with acute and chronic respiratory infections (D).
- Patients with infectious tuberculosis (TB) must not travel by public air transportation. (C) WHO guidelines state that 'physicians should inform all infectious and potentially infectious TB patients that they must not travel by air on any commercial flight of any duration until they are sputum smear-negative on at least two occasions'. This may be overcautious. Patients in whom drug-resistant TB is not suspected and who have completed 2 weeks of effective antituberculous treatment are in practice generally considered non-infectious.[32]
- Patients with multi-drug resistant TB (MDR-TB), extremely drug resistant TB (XDR-TB) or totally drug resistant TB (TDR-TB) must not travel on any commercial flight, whatever the duration, under any circumstances, until they are proven to be non-infectious with two consecutive negative sputum culture results (C).
- The latest web-based guidelines (national and/or international) should be consulted for travel restrictions regarding cases or contacts of patients with respiratory viral infections of high mortality, such as severe acute respiratory syndrome (SARS). (D) This is especially important for outbreaks of emerging respiratory infection. Updates are available on the WHO site (http://www.who.int/).

HIV infection

- HIV-positive passengers should check beforehand with the embassies of the countries they are visiting for visa requirements or travel restrictions (D).
- General measures minimise risk of exposure to blood-borne viruses and are appropriate for all settings where passengers are bleeding, whether or not they are HIV-positive. (C) Guidance is available from the UK Department of Health (http://www.dh.gov.uk/).
- Some HIV-positive passengers are at risk of developing opportunistic infection (OI). Patients are usually not deemed fit to travel during the acute phase of an OI (D).
- The patient's physician should advise whether a patient recently treated for OI is fit to travel. (D) Airline guidance should also be sought.
- Advice on pre-flight vaccination is available in current British HIV Association guidelines[33] (http://www.bhiva.org/) (D).
- Patients should carry a supply of antiviral drugs and other medication in hand luggage. If they forget to take an antiviral dose, they should take the next dose as soon as practical and then revert to their normal schedule (D).

Interstitial lung disease

- Patients should be carefully assessed as previously described (D).
- Oxygen should be considered if staying at high altitude destinations (D).
- An emergency supply of antibiotics with or without prednisolone is prudent, with medical advice on managing steroid dose during intercurrent illness if the patient is already taking oral corticosteroids (D).

Neuromuscular disease and kyphoscoliosis

- All patients with severe extrapulmonary restriction, including those needing home ventilation, should undergo HCT before travel (C).

- The decision to recommend in-flight oxygen and/or non-invasive ventilation must be made on an individual clinical basis (D).

Obstructive sleep apnoea syndrome

A doctor's letter is required outlining the diagnosis and necessary equipment. It should state that the continuous positive airway pressure (CPAP) machine should travel in the cabin as extra hand luggage (some airlines treat this as excess luggage). A fact sheet for passengers to show airport security personnel is available from the American Sleep Apnea Association (http://www.sleepapnea.org/)

- Alcohol and sedatives should be avoided before and during travel (D).
- A/C power is not usually available on board and passengers should use dry cell batteries; dry cell battery-powered CPAP can be used throughout except during take-off and landing (D).
- CPAP machines used in-flight should be capable of performing adequately in the low pressure cabin environment (D).
- Patients should check that their CPAP device is compatible with the altitude and power supply at their destination and that a power supply is within reach of the bed (D).

Obesity

- Obese passengers may have difficulty fitting into standard airline seats and should check in advance with the airline that one seat is sufficient (D).
- Those with body mass index (BMI) $>30\ kg/m^2$ should be considered at moderately increased risk of venous thromboembolism (VTE) and follow advice for those travelling for >8 h (D).

Pneumothorax

- Patients with a closed pneumothorax should not travel on commercial flights (with the exception of the very rare case of a loculated or chronic localised air collection which has been very carefully evaluated) (C).
- Patients who have had a pneumothorax must have a chest x-ray to confirm resolution before flight. Many would regard it as prudent for a further 7 days to elapse before embarking upon flight (C).
- In the case of a traumatic pneumothorax, the delay after full radiographic resolution should ideally be 2 weeks (D).
- A definitive surgical intervention undertaken via thoracotomy is likely to be entirely successful and patients should be allowed to fly once they have recovered from surgery. (D) A similar intervention undertaken by video-assisted thoracoscopic surgery is also expected to have a high success rate but is not definitive; these patients should be aware of a slight risk of recurrence (B).
- Patients having other forms of pleurodesis and those not undergoing pleurodesis after a pneumothorax are unlikely to have further episodes precipitated by flight, but spontaneous recurrence could have important consequences in the absence of prompt medical care. The risk of recurrence is higher in those with coexisting lung disease and does not fall significantly for at least 1 year. Those not undergoing definitive surgery may therefore wish to consider alternative forms of transport (D).
- Patients with lymphangioleiomyomatosis should be advised that they are at increased risk of pneumothorax and that any unusual clinical symptoms such as chest pain or breathlessness should preclude air travel until fully evaluated (D).

Pulmonary arteriovenous malformations (PAVMs)

- Patients with PAVM with or without significant hypoxaemia should be considered at moderately increased risk of VTE (D).
- Patients with PAVM with a previous VTE or embolic stroke should receive a single dose of low molecular weight heparin before the outward and return journeys (D).
- Patients with PAVM with severe hypoxaemia may benefit from in-flight oxygen (D).
- For patients with PAVM with previous VTE or embolic stroke in whom embolisation is planned, deferring long-haul non-medical flights may be advisable until embolisation is complete (D).

Sinus and middle ear disease

- Adults with risk factors for sinus or middle ear barotrauma (mucosal oedema, bacterial infection, thick mucin, intrasinus and extrasinus pathology and tumours) should receive an oral decongestant before travel and a nasal decongestant spray during the flight just before descent (D).
- Women in the first trimester of pregnancy may wish to take intranasal steroids instead of topical decongestants (D).
- Passengers who develop sinus barotrauma after flying should receive topical and oral decongestants, analgesics and oral steroids (D).
- Antibiotics are advised if bacterial sinusitis is thought to be the trigger, and antihistamines if allergic rhinitis is suspected (D).
- Symptoms and signs of barotrauma should have resolved before flying again; some recommend plain radiography to ensure that mucosal swelling has settled. This usually takes at least a week and may take up to 6 weeks (D).
- Recurrent sinus barotrauma is usually only seen in military air crew and has been shown to respond to functional endoscopic sinus surgery (D).

Thoracic surgery

- In patients who have undergone thoracic surgery with drain insertion, chest radiography is required after drain removal to ensure full expansion of the lung (C).
- Patients who have a pneumothorax after drain removal should not travel on commercial flights until full re-expansion has been confirmed on chest radiography (C).
- If chest radiography after drain removal confirms full re-expansion, it is prudent to wait for 7 days before air travel (D).
- Any symptoms or signs suggesting the possibility of a pneumothorax after drain removal should prompt a further chest x-ray before air travel (C).

Venous thromboembolism (VTE) for flights >8 h or multiple shorter journeys over a short period

The evidence is unclear, current guidelines conflicting and recommendations controversial. Patients are usually stratified into three groups, but physicians may wish to make decisions on an individual case-by-case basis as the evidence for any particular recommendation is limited and firm guidelines cannot be formulated. The risk of VTE is greatest on flights lasting >8 h and is reduced if passengers occupy an aisle seat.

Low risk of VTE: all passengers not in the categories listed below.

- Passengers should avoid excess alcohol and caffeine-containing drinks, and preferably remain mobile and/or exercise their legs during the flight (D).

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Moderately increased risk of VTE: family history of VTE, past history of provoked VTE, thrombophilia, obesity (BMI >30 kg/m^2), height >1.90 m or <1.60 m, significant medical illness within previous 6 weeks, cardiac disease, immobility, pregnancy or oestrogen therapy (including hormone replacement therapy and some types of oral contraception) and postnatal patients within 2 weeks of delivery.

- Patients should be advised to wear below-knee elastic compression stockings as well as the following recommendations for low-risk passengers. They should be advised against the use of sedatives or sleeping for prolonged periods in abnormal positions. (D) Passengers with varicose veins may be at risk of superficial thrombophlebitis with use of stockings; the risk/benefit ratio here is unclear.

Greatest increased risk of VTE: past history of idiopathic VTE, those within 6 weeks of major surgery or trauma and active malignancy

There is no evidence to support the use of low- or high-dose aspirin.

- Pre-flight prophylactic dose of low molecular heparin should be considered or formal anticoagulation to achieve a stable INR of 2–3 for both outward and return journeys, and decisions made on a case-by-case basis. These recommendations are in addition to general advice for those at low to moderate risk (D).
- Patients who have had a VTE should ideally not travel for 4 weeks or until proximal (above-knee) deep vein thrombosis has been treated and symptoms resolved, with no evidence of pre- or post-exercise desaturation. (D)

BACKGROUND LITERATURE REVIEW

The flight environment and effects of altitude

To understand fully the implications of air travel for clinical pathophysiology, it is essential to appreciate the nature of the atmosphere and the physical consequences of ascent to altitude.

The atmosphere can be viewed as a series of concentric 'shells' around the Earth, which are not of equal or constant depth. Most air travel occurs within the innermost shell, the troposphere, which extends from sea level to an altitude of 36 069 ft (10 980 m) at temperate latitudes, 26 000 ft (7925 m) at the poles, and up to 60 000 ft (18 288 m) at the equator.

The troposphere is characterised by a relatively constant decline in temperature on ascent at a rate of 1.98°C/1000 ft until the edge of the troposphere, the tropopause, is reached. Above this altitude the temperature remains constant at −56°C. Although temperature declines at a constant rate, atmospheric pressure declines exponentially. Sea level pressure is defined for standardisation purposes as 760 mm Hg, and the essentially exponential reduction in ambient pressure on ascent means that atmospheric pressure has halved at 18 000 ft and roughly halves again every further 18 000 ft of ascent (see figure 1 and Appendix 7). Consequently, even a relatively modest ascent results in a greater reduction in ambient atmospheric pressure than might otherwise be expected.

The chemical composition of the troposphere is constant: oxygen 21%, nitrogen 78% and 1% other gases (including argon and carbon dioxide, the latter present at 0.03%). It is therefore the fall in partial pressure of oxygen as total ambient pressure falls on ascent that gives rise to hypobaric hypoxia, not a fall in the percentage of oxygen within atmospheric air.

Dalton's law of partial pressures states that the pressure exerted by a mixture of gases is equal to the sum of the pressures each would exert if it occupied the space filled by the mixture alone.[19] This means that the composition of air is constant at any given altitude but the partial pressure of each component reduces with ascent to altitude. Thus, at 8000 ft inspired oxygen tension is 108 mm Hg, falling from 148 mm Hg at sea level. This equates to breathing 15.1% oxygen at sea level. In a normal healthy individual this results in a fall in arterial oxygen tension (Pa_{O_2}) to 7.0–8.5 kPa (53–64 mm Hg, oxygen saturation measured by pulse oximetry (Sp_{O_2}) 85–91%), which does not usually cause symptoms.

The normal physiological response to altitude hypoxaemia is well described.[19 34] Hypoxia stimulates peripheral chemoreceptors in the carotid bodies producing hyperventilation, with an increase in tidal volume effected by increased minute ventilation to maximise alveolar oxygen tension (P_{AO_2}) and Pa_{O_2}. The alveolar–arterial oxygen gradient falls. Hypoxic pulmonary vasoconstriction causes increased pulmonary arterial pressure and pulmonary vascular resistance, which is benign and reversible. Arterial carbon dioxide tension (Pa_{CO_2}) falls as a result of hyperventilation, but hypoxia overcomes the cerebral vasoconstrictor effect and maintains oxygen delivery to the brain. Cardiac output increases as a result of tachycardia, maintaining blood flow and oxygen delivery.

The changes in pressure and temperature have other physical effects as predicted by the gas laws. Since body temperature remains essentially constant, the fall in ambient temperature usually induces fewer adverse consequences than the change in ambient pressure. Boyle's law predicts that, as pressure falls, the volume of a gas will increase proportionately (at a constant temperature) with a 38% expansion of humidified gas (see figure 2 and Appendix 7). This affects all gas-filled cavities of the body, but in the lungs there is relatively free communication with cabin air so that gas trapping is rarely of serious concern. In cavities where gas communication is more limited such as the middle ear and sinuses, problems can arise on ascent and descent, markedly exacerbating any inflammation present.

Commercial aircraft commonly cruise at altitudes of around 38 000 ft in order to avoid air turbulence and reduce drag, thereby improving fuel economy. Aircraft cabins are therefore pressurised so that the effective altitude to which occupants are exposed is much lower than that at which they are flying. Commercial aircraft are not pressurised to sea level but to a relatively modest intermediate cabin altitude. This is for reasons of weight and cost, and also because of concerns about shortening the working life of the aluminium airframe.

Aircraft cabin altitudes can approach 8000 ft (2438 m) when flying at 38 000 ft (11 582 m), and a pressure differential exists across the cabin wall, commonly of up to 9 lb/sq in in existing aircraft. US Federal aviation regulations[35] stipulate that, at a plane's maximum cruising altitude, the cabin altitude should not exceed 8000 ft (2438 m) except in an emergency. Thus almost all current commercial aircraft operate to maximum, although it may not be reached in all flights, especially short ones.

The aircraft cabin is pressurised by outside air drawn into the cabin from the engine. This superheated air is cooled, and cabin pressure is determined by the rate of air intake and of air output through a regulated exhaust valve.[36] The precise cabin altitude depends on the altitude of the aircraft and aircraft type. Cabin altitude thus varies not only according to the aircraft's altitude, but also between different aircraft flying at the same altitude.[37]

One study of in-flight cabin altitudes on 204 scheduled commercial aircraft flights reported variations in cabin altitude ranging from sea level to 8915 ft (2717 m), with a mean of 6214 ft (1894 m).[38] The Boeing 787 Dreamliner is expected to operate with a maximum cabin altitude of 6000 ft (1829 m).

The benefit of adopting a lower cabin altitude is supported by a study sponsored by the aircraft manufacturer which reported an increased incidence of subject discomfort after exposure to 7000–8000 ft for 3–9 h.[39]

In the event of cabin decompression at high altitude, all occupants require immediate supplemental oxygen to prevent dangerous hypoxia. Commercial aircraft are equipped with emergency oxygen for passengers, demonstrated before every flight in accordance with civil aviation regulations. The emergency oxygen supply will protect a healthy individual from dangerous hypoxia for around 15 min. In that time the flight crew are expected to descend the aircraft to a less hazardous altitude. However, some passengers with impaired respiratory function may be particularly susceptible to the effects of ascent even to normal cabin altitudes. These recommendations apply only to larger commercial aircraft and not to small private or unpressurised aircraft operating under general aviation regulations.

Clinical pre-flight assessment in adults

An audit of 109 applications for in-flight oxygen conducted by a major UK airline showed that they are rarely provided with objective information to assess risk, only 61% of requests including simple data such as oximetry or spirometry (M Popplestone, personal communication, 2004). In the absence of such information, airlines traditionally favour the 50 m walk test. Other methods used to assess whether patients are fit to fly include predicting hypoxaemia from equations (see appendix 8) and the hypoxic challenge test (HCT).

Walk tests

The ability to walk 50 m without distress, previously favoured by airlines, has the merit of being simple, but is often the only subject of enquiry and not verified. There is no evidence validating this test. Although apparently a crude assessment, the ability to increase minute ventilation and cardiac output in response to an exercise load is a good test of cardiorespiratory reserve. It is also a common-sense approach to simulating the stress of the additional hypoxaemia patients will experience at rest during a flight. Respiratory physicians have experience of walk tests in other contexts, including the 6 or 12 min walk test and the shuttle walk test.[40–42] Such tests are now commonly used when assessing patients for lung volume reduction surgery and lung transplantation.

If performed, the walk test should be the test usually conducted in that laboratory. Failure to complete the task (whether distance or time), or moderate to severe respiratory distress as recorded on a visual analogue scale, will alert the physician to a possible need for in-flight oxygen. Walk tests are clearly unsuitable for those with significantly impaired mobility.

Predicting hypoxaemia from equations

Some centres use one of several equations predicting Pa_{O_2} or Sp_{O_2} from sea level measurements.[43–47] The equations have been derived almost exclusively from patients with chronic obstructive pulmonary disease (COPD) who have had Pa_{O_2} measured in a hypobaric chamber, or before and during exposure to simulated altitude while breathing 15% inspired oxygen from a reservoir bag. Measuring FEV_1 may improve the accuracy of predicted values.[44 45] One weakness is that the 90% confidence limits are ±1 kPa (±2–4% Sp_{O_2}). However, the predictions are usually reliable enough to establish upper and lower thresholds for 'no in-flight oxygen required'. Flight duration and cabin conditions are obviously not reproduced.

Hypoxic challenge test (HCT)

The ideal test, exposing a subject to hypoxia in a hypobaric chamber, is not widely available. The HCT as described by Gong[46] is therefore often used. It assumes that breathing hypoxic gas mixtures at sea level (normobaric hypoxia) equates to the hypobaric hypoxia of altitude.[48] The maximum cabin altitude of 8000 ft (2438 m) can be simulated at sea level with a gas mixture containing 15% oxygen in nitrogen. Subjects are usually asked to breathe the hypoxic gas mixture for 20 min or until equilibration. Saturation is monitored throughout and arterial blood gases or Sp_{O_2} measured beforehand and on completion. Flight duration and cabin conditions are clearly not reproduced.

Fifteen per cent oxygen can be administered in several ways. Oxygen and nitrogen can be mixed in appropriate proportions in a Douglas bag or laboratories can buy cylinders of 15% oxygen in nitrogen. The gas mixture can be given via a non-re-breathing valve, either through a mouthpiece or a tight-fitting face mask. A modified body plethysmograph can also be filled with a gas mixture containing 15% oxygen to provide a hypoxic environment without the need for a face mask or mouthpiece.[49] This allows oxygen requirements to be titrated accurately using nasal cannulae to supply oxygen to the patient within the body box. A similar unpublished suggestion is to use a hood over the subject's head, filled with 15% oxygen. Finally, similar levels of hypoxic gas mixtures can be given with a commercial 40% venturi mask if 100% nitrogen is used as the driving gas. The entrained air dilutes the nitrogen, producing a 14–15% oxygen mixture under experimental conditions in subjects with a range of respiratory conditions.[50] Although probably inferior to a modified body plethysmograph, the venturi mask method is inexpensive and well tolerated.[4]

A subject is usually judged to require in-flight oxygen if the Pa_{O_2} falls below 6.6 kPa (50 mm Hg) or Sp_{O_2} falls below 85%.[49] These apparently arbitrary figures have little supporting evidence, but many physicians have accepted them as reasonable. A study of 131 patients[51] has shown that, for patients with a resting sea level Sp_{O_2} >95%, there was no desaturation below 90% during the HCT. The data suggested that all patients with sea level Sp_{O_2} <95% should undergo HCT as some patients without any existing predefined risk factors showed significant desaturation during hypoxic challenge. A recent study by Akerø *et al*[7] suggested that simple Sp_{O_2} measurement is insufficient in COPD to identify patients who need in-flight oxygen. Kelly *et al*[52] suggested that other measurements such as carbon monoxide transfer factor (T_{LCO}) provide additional information which improves the ability to predict the response to altitude in COPD. Akerø *et al*[53] showed that, during a commercial flight lasting over 5 h, 18 patients with COPD showed an initial reduction in Pa_{O_2} which then remained stable during the flight. HCT is the pre-flight test of choice in hypercapnia, but there are few published studies examining how hypercapnia alters fitness to fly.

Several studies published since 2004 have confirmed previous data suggesting that neither resting sea level oxygen saturations nor FEV_1 reliably predict hypoxaemia or complications during or after air travel in patients with pulmonary disease.[3–7] There is thus no reliable threshold in these parameters which enables clinicians to determine with accuracy the safety of air travel or the need for in-flight oxygen. When compared with hypobaric chamber exposure, HCT has been shown to reliably identify patients needing supplemental oxygen[54] and is thus still the method of choice, but there is a need to define the role of walk

tests or a symptom-based approach using, for example, the MRC dyspnoea scale.[24]

Clinical pre-flight assessment in infants and children

- *For infants born at term (>37 weeks) it is prudent to wait for 1 week after birth term (corrected gestational age 40 weeks) before flying to ensure they are healthy (√)*

The incidence of in-flight paediatric respiratory emergencies is unknown as there is no central national or international registry. One study of an 8-year period for a single US commercial airline reported 169 paediatric emergencies of which 22 were respiratory.[55] The presence of pre-existing lung disease in these children was not reported. Since the first BTS recommendations in 2002 and 2004,[1 2] evidence has accumulated to show that there is an increased risk of symptomatic hypoxia in very young infants (especially preterm infants) who fly.[56] Some of the evidence has influenced recently revised US[20] and Canadian[57] guidelines.

The physiology of the child's lungs differs from that of adults. During early life, compliance is lower while residual volume and airway resistance are higher.[58] In the neonatal period regional lung perfusion may remain labile, with estimates of a persistent 10% right-to-left pulmonary shunt in healthy infants at 1 week of age.[59] Fetal haemoglobin is present in significant amounts up to 3 months of age. Its effect on the oxygen dissociation curve is to enhance oxygen loading in a hypoxic environment, but possibly to decrease unloading in peripheral tissues.[60] Some of these factors may explain why the response to a hypoxic environment is less predictable in infants than it is in adults. There are few data on the Sp_{O_2} in normal healthy infants and children exposed to cabin altitudes. A study by Lee *et al*[11] examined Sp_{O_2} in 80 children aged 6 months to 14 years during prolonged commercial air travel. Saturation declined significantly during flight. Average sea level Sp_{O_2} was 98.4%, falling to 95.7% after 3 h and to 94.4% after 7 h. This was associated with reduced cabin partial pressure of oxygen (159 mm Hg at sea level, 126 mm Hg after 3 h and 124 mm Hg after 7 h), but the marked difference between Sp_{O_2} at 3 and 7 h suggests that flight duration may contribute to worsened oxygen desaturation. However, no child became symptomatic.

The following key questions arise:

Should preterm infants who have not yet reached term undergo HCT?

- *Infants born prematurely (<37 weeks) with or without a history of respiratory disease who have not yet reached their expected date of delivery do not require HCT, which is unreliable in this group,[25] but should have in-flight oxygen available and delivered at 1–2 l/min if they develop tachypnoea, recession or other signs of respiratory distress) (C)*

A study from Perth, Australia observed that, in preterm infants, Sp_{O_2} during flight may fall below 85% in the absence of any history of respiratory problems. In their study, 16 out of 46 preterm infants (gestational age at time of flight 35–37 weeks) flying back to regional hospitals from a tertiary neonatal unit required supplementary oxygen.[25] Five of these 16 infants had no history of neonatal lung disease or requirement for oxygen. During the flight, seven of the 16 infants who required oxygen were symptomatic. Desaturation became evident while asleep rather than when awake. The HCT used in this study failed to predict those infants who desaturated. The duration of HCT has been the subject of some debate. One study investigating the effects of a prolonged HCT (mean duration 6.3 h) on sleeping healthy infants aged 1–6 months found that four out of 34 infants had significant desaturation <80% at times between 1.9 and 5.2 h. The relevance of these findings is unclear.[61] Laboratory-simulated flight hypoxia is not necessarily identical to that incurred when flying at altitude.[25 62–64] Factors such as humidity, noise, vibration and sleep/wake states may all influence the pattern of breathing during flight.

Should infants and young children with a history of chronic lung disease undergo a fitness to fly test?

- *Infants under 1 year with a history of neonatal chronic respiratory problems should be discussed with a specialist respiratory paediatrician and HCT performed. Infants with Sp_{O_2} <85% on testing should have in-flight oxygen available (D); paediatrician discretion should be used for infants with Sp_{O_2} 85–90% and, where there is doubt, the doctor should err on the side of caution (√)*
- *Infants and children who are oxygen-dependent at sea level will need their oxygen flow rate doubled at cruising altitude and should not need HCT (C)*
- *Infants and children who have had long-term oxygen in the last 6 months should have HCT (D)*

Chronic lung disease may complicate preterm birth and persist after the infant reaches the expected date of delivery. Some of these infants may require supplementary oxygen even at sea level for several months into the first or second year of life. When trying to predict the need for in-flight oxygen, it is unclear what test is most appropriate for small children and there has been debate about whether to use 90% or 85% as the threshold value below which in-flight oxygen is recommended.[63] Studies evaluating the need for oxygen during flight in infants with lung disease have found that sea level Sp_{O_2} is an unreliable predictor of Sp_{O_2} in a hypoxic environment.[25 62 64–66]

Only one of these studies also measured outcomes during flight[25]; it found that HCT was a poor predictor of in-flight desaturation. In a group of 35 infants with a history of neonatal chronic lung disease compared with 34 control infants in the first year of life, the Perth group found a cut-off of 85% more discriminating than 90% using a face mask to deliver 14% fractional inspired oxygen (Fi_{O_2}). No child became symptomatic. The study did not record flight outcomes.[66] A subsequent study on 46 preterm infants by the same group concluded that, irrespective of whether 85% or 90% was used as the cut-off value, pre-flight testing using a face mask could not accurately predict which preterm infant would require in-flight oxygen. The authors suggested abandoning pre-flight tests in favour of monitoring high-risk preterm infants during air travel with oxygen available if needed.[25]

Our 2004 statement advised exposing the infant or child to 15% Fi_{O_2} while on the carer's lap in a whole body box. This technique has the advantage of being non-invasive. The Perth group have suggested that, where a body box is not available, a tight fitting non-rebreathing mask may be applied to the child's face through which high-flow 14% oxygen is administered (see box 1).[67] This approach may be less well tolerated[66] and there has been no direct comparison of the two techniques.

Despite the lack of evidence, it is suggested that infants with a history of chronic lung disease who have passed their expected date of delivery are discussed with a specialist respiratory paediatrician. The decision to perform HCT will depend on the child's current respiratory status and interval since they last needed oxygen. If it is <6 months, HCT is advised.[68] Where HCT is performed, it is recommended that the 85% cut-off is used as an indication for supplementary oxygen delivered at 1–2 l/min.

Should older children with a history of significant chronic lung disease including cystic fibrosis (CF) undergo a fitness to fly test?

- *In children with CF or other chronic lung diseases who are old enough for spirometry and whose FEV_1 is <50% predicted, HCT is recommended. If Spo_2 falls below 90%, in-flight oxygen is advised (C)*

Older children with chronic lung diseases such as CF may be better adapted to a hypoxic environment, possibly through changes in haemoglobin oxygen dissociation characteristics. Two studies on young people with CF evaluated HCT as a predictor of the need for in-flight oxygen.[62 63] Both studies measured outcomes during flight. The latter study of 87 children with CF suggested that, in children old enough to do spirometry, FEV_1 <50% predicted is a better predictor than HCT of Spo_2 <90%.[62] In neither of these studies did children who desaturated <90% become symptomatic.

Is it safe for children with a history of asthma to fly?

There are no data enabling one to predict when it is safe to fly after an acute asthma attack. It would be prudent for any child flying with well-controlled asthma to take their regular preventer and reliever medicines on board.[56]

Is it safe for a child with a history of pneumothorax and/or cystic lung conditions to fly?

There is no evidence to suggest that a child with a recent history of pneumothorax is at a different risk from an adult.[56] Following a pneumothorax it would seem prudent, as in adults, to ensure that a chest x-ray is taken to check resolution before air travel, and delay travel for 7 days after a spontaneous event and 14 days after a traumatic pneumothorax.

Intrapulmonary cysts connected to the airways should not present a problem during air travel since the pressure inside the cyst will equalise with that in the cabin. The situation for completely encysted air spaces, such as those found with some congenital malformations, is completely different. The risk in children should not differ from that in adults. Many cysts are asymptomatic and only detected during antenatal ultrasound scans; even if surgery is planned, it is often delayed until the child is at least 2 years old. Although cysts do not generally pose a problem, there is a case report of a 17-year-old with a large congenital cyst, of which the patient was unaware, who developed a cerebral air embolus during flight, presumably due to its rupture.[69] The patient had previously flown without complications. It is thus difficult to give firm recommendations, but it would seem reasonable for parents to be made aware of the risk—albeit low—so that elective surgery can be considered.[56]

In postinfective pneumatoceles, although the encysted air will expand by 38% at altitude, their relatively small size means this should not have a significant impact. However, it would be prudent to ensure that large intrapulmonary air spaces have resolved radiographically before travel. Intrapleural air after a complex empyema should be treated as a pneumothorax.

What about respiratory infection in infancy?

Infants (especially those born prematurely before 32 weeks gestation) who develop an acute viral respiratory infection are known to be at risk of apnoea, apparently because they revert to a more immature pattern of breathing.[70 71] Exposure to a hypoxic environment at this time may increase the risk of apnoea.[60] It is suggested that ex-premature infants should delay flying for 6 months after the expected date of delivery if they develop signs of lower respiratory infection (such as wheeze, cough or tachypnoea) or a significant upper respiratory tract infection.

Risk of respiratory cross-infection

Although the potential risk of cross-infection would seem high in the closely confined space of the airline cabin, the evidence is that such cross-infection is minimal.[72] In modern aircraft the cabin air is recirculated through high-efficiency air filters up to 20 times per hour and cabin flow of air is vertical rather than horizontal.[56] Tuberculosis (TB) and influenza cross-infection in the cabin environment have been reported.[73 74] In neither incident were children involved. Nevertheless, a child with TB should delay flying until no longer infectious, and a child with influenza should not fly until fully recovered.

Middle ear barotrauma

This can result from failure to equilibrate the middle ear and atmospheric pressure difference, and tends to occur most often during descent. Children are especially at risk for several reasons.[56] They have narrower eustachian tubes, are less able to regulate the pressure difference by performing a Valsalva manoeuvre, are more likely to suffer from viral head colds and more likely to have adenoidal tissue obstructing the eustachian tube orifice. Parents should be advised to encourage their children to drink, chew, suck and blow their nose, particularly during descent, to prevent barotrauma. There are currently no data to support using pseudoephedrine pre-flight in children with ear pain or nasal congestion or to prevent children with otitis media from flying.

Respiratory disorders with potential complications for air travellers

A summary of the potential risks posed by air travel in various conditions is shown in table 2.

Airways disease (asthma and COPD)

- *For an acute exacerbation on board, the patient's own bronchodilator inhaler (or airline emergency kit inhaler if available) should be administered, with a spacer where appropriate, and the dose repeated until symptomatic relief is obtained (D)*
- *Patients with severe or brittle asthma or severe COPD (FEV_1 <30% predicted) should consult their respiratory specialist beforehand and consider taking an emergency supply of prednisolone in their hand luggage as well as supplies of their usual medications (D)*

Asthma

The commercial flight environment does not usually pose problems for those with asthma. The main risk is of bronchospasm induced by bronchial mucosal water loss resulting from low cabin humidity. Hypobaric hypoxia should not present a significant risk, and reduced cabin ambient pressure should not affect patients with no comorbidity.

Limited data exist on the physiological effect of the flight environment in asthma. In a study to examine the effect of reduced barometric pressure on exercise-induced bronchoconstriction, Berntsen *et al*[75] subjected 20 subjects with asthma (age 10–45 years) to exercise testing at sea level and 2500 m in random order on separate days. They measured lung function, heart rate, oxygen uptake, Spo_2, gas exchange and minute ventilation. Mean Spo_2 fell from 94.4% to 85.6% but there was no increase in exercise-induced bronchospasm. Other studies in subjects with asthma travelling to high altitude destinations have recorded bronchospasm resulting from heat and water loss from the bronchial mucosa.[76 77]

Table 2 Summary of potential risks posed by air travel in various conditions

Condition	Risk
Asthma and COPD	Acute bronchospasm, hypoxaemia or infective exacerbation*
Bronchiectasis	Hypoxaemia, infective exacerbation*
Lung cancer	Hypoxaemia, overall deterioration or sepsis
Cardiac comorbidity	Myocardial ischaemia; hypoxaemia, arrhythmia, peripheral oedema, venous thromboembolism, worsening of heart failure
Hyperventilation and dysfunctional breathing	Acute exacerbation
Airborne infections	Hypoxia, transmission to other passengers
HIV infection	Exacerbation of pre-existing opportunistic infection
Interstitial lung disease	Hypoxaemia, infective exacerbation*
Neuromuscular disease and kyphoscoliosis	Hypoxaemia
OSAS	Worsening hypoxaemia when asleep, exacerbation of jet lag with potential adverse effect on driving
Obesity	Difficulty fitting into standard airline seats, worsening hypoxaemia in obesity hypoventilation syndrome, VTE
Pneumothorax	38% expansion of residual air at 8000 ft (2438 m); possible recurrence within at least 1 year unless pleurodesis has beenperformed via thoracotomy
PAVMs	Hypoxaemia, stroke, VTE and PAVM haemorrhage
Sinus and middle ear disease	Sinus or middle ear barotraumas
Thoracic surgery	38% expansion of residual air at 8000 ft (2438 m)
At risk of VTE	Increased risk of VTE on all flights especially those >8 h or following multiple shorter journeys over a short period

*Infective exacerbation is possible because of proximity to others with contagious diseases (ie, resulting from direct person-to-person transmission).
COPD, chronic obstructive pulmonary disease; OSAS, obstructive sleep apnoea syndrome; PAVM, pulmonary arteriovenous malformation; VTE, venous thromboembolism.

Several studies[29 78–83] report a frequency of in-flight respiratory medical events of around 10% but do not specify asthma per se as the cause. Severe asthma appears rare, although fatalities have been reported.[83] In a retrospective study from the Royal College of Surgeons in Edinburgh,[84] 65% of events occurred in travellers with pre-existing medical conditions, of which 21% were respiratory. No respiratory events were reported in passengers without pre-existing conditions. One-third of those suffering an asthma attack had forgotten their medication or left it in their hold baggage. Dowdall[29] reports asthma as the commonest potentially life-threatening condition on British Airways flights, but most episodes are minor and result from having left medication in the hold baggage.

In the UK Flight Outcomes Study[6] 15% of the subjects had asthma; all were under specialist care. No deaths were reported in this group. While breathlessness in-flight and an increased need for antibiotics after travel were noted, the study does not suggest that patients with asthma are particularly at risk. Overall it seems reasonable to conclude that commercial air travel is safe for patients with well-controlled asthma and those under specialist supervision.

COPD

Passengers with COPD are potentially at risk from reduced partial pressure of oxygen and expansion of gases within closed body cavities (bullae and pneumothoraces). In COPD, a low inspired oxygen tension has potential for greater adverse effects. Several factors may influence the response to altitude-induced hypoxaemia, including pre-existing hypoventilation, ventilation-perfusion mismatch, impaired diffusion or low mixed venous oxygen saturation; the rate of ascent, cabin altitude and flight duration; airway resistance, position on the oxygen dissociation curve, exercise taken at altitude and comorbidity.[85] Several studies have examined the effect of altitude-induced hypoxaemia in COPD, either simulated in the lung function laboratory or in a hypobaric chamber. Some have examined passengers with COPD during flight; others have investigated flight outcomes. The studies are generally small, making it difficult to draw firm conclusions.

Gong *et al* in their original publication of the hypoxia altitude simulation test[46] studied 22 patients with stable mild COPD (FEV_1 <80% predicted), 17 of whom reported chest tightness or dyspnoea on previous flights. They inhaled sequential gas mixtures of 20.9% (sea level), 17.1% (simulating 1524 m), 15.1% (simulating 2438 m), 13.9% (simulating 3048 m) and 20.9% oxygen (sea level recovery). With 15.1% inspired oxygen, Sp_{O_2} fell from 94% to 83%. The lowest readings were 87% on 21% Fi_{O_2} and 74% on 15.1% Fi_{O_2}. Progressive mild hypoxia-induced hyperventilation caused small but significant falls in Pa_{CO_2}. Supplemental oxygen, given during inhalation of 15.1% oxygen in five subjects and 13.9% oxygen in 16, increased Pa_{O_2}. Pa_{CO_2} returned to baseline with oxygen and in eight subjects rose slightly above baseline. Heart rate rose and asymptomatic cardiac dysrrhythmias occurred in 10 subjects. Blood pressure was unchanged. Eleven reported mild symptoms unrelated to Fi_{O_2} or hypoxaemia. Sleepiness noted by investigators was partly reversed by supplemental oxygen.

Several authors have tried to identify factors which might predict hypoxia at altitude. Dillard[45] undertook a prospective study of 18 retired servicemen exposed to 8000 ft (2438 m) in a hypobaric chamber for 45 min. He showed correlations between Pa_{O_2} and FEV_1 at ground level with Pa_{O_2} at altitude. However, Robson *et al*,[4] in a small study of patients undergoing HCT using Vohre and Klocke's method,[50] found that neither FEV_1 nor pre-test Sp_{O_2} predicted hypoxaemia at simulated altitude. Schwartz *et al*[3] measured arterial blood gases at 1650 m and 2250 m in 13 patients with COPD during flight in an unpressurised aircraft. There was no correlation with arterial blood gas measurements performed several weeks before flying, but there was a correlation with Pa_{O_2} measured 2 h before flight whether breathing room air or 17.2% Fi_{O_2}. Dillard *et al* published a meta-analysis of hypoxaemia during altitude exposure in COPD.[44] The fall in Pa_{O_2} per unit change in inspired oxygen pressure (Pi_{O_2}) correlated negatively with FEV_1 in all studies, the largest falls in Pa_{O_2} per unit change in Pi_{O_2} occurring in those with the lowest FEV_1. The authors concluded that these data support FEV_1 as a predictor of Pa_{O_2} at altitude in COPD.

Mortazavi and colleagues[86] have reviewed the acute response to hypoxia. In COPD, hypoxia-induced pulmonary vasoconstriction at altitude may improve ventilation-perfusion mismatch seen at sea level, thus limiting resulting hypoxaemia. Oxygen diffusion across the alveolar capillary membrane is limited by the lower P_{AO_2} at altitude, and this diffusion limitation is exacerbated by exercise as a result of shortened capillary transit time. This diffusion limitation contributes significantly to the risk of hypoxia in COPD.

Dillard *et al*[87] hypothesised that, if lung function tests at sea level suggested poor tolerance to altitude hypoxaemia, then further decline in pulmonary function at altitude would be detrimental. This study reported a fall in forced vital capacity (FVC) in six patients with COPD and three healthy subjects at altitude which correlated with changes in maximum voluntary ventilation but not with worsening of arterial blood gases. Thus, in this small study, there was no worsening of hypoxaemia at altitude with falling spirometric parameters. Berg *et al*[88] studied the effect of vasopressor responses to hypoxia in 18 subjects with severe COPD undergoing hypobaric chamber hypoxaemia at 2438 m for 45 min. Vasopressor responses to hypoxia did not appear to increase the risk from altitude exposure.

Airline medical departments have traditionally used the unvalidated 50 m walk test.[23] Chetta *et al*[89] examined the ability of the validated 6 min walk test[40] to predict altitude hypoxaemia measured using HCT. They showed a significant relationship between mean 6 min walk Sp_{O_2} and mean HCT Sp_{O_2}.

The lack of consensus could partly reflect the use of different tests to simulate altitude-induced hypoxia. Dillard *et al*[48] compared HCT with hypobaric chamber exposure at 8000 ft (2438 m) in patients with COPD and in healthy subjects. The two tests produced comparable changes in Pa_{O_2}. Martin *et al*[90] compared HCT with four predictive equations[1] in 15 patients with COPD. With the exception of equation 3, they found poor agreement between Pa_{O_2} values during HCT and those derived from predictive equations. Overall, using predictive equations would have increased in-flight oxygen prescriptions.

The effect of supplemental oxygen has been evaluated by Berg *et al*[91] in 18 patients with severe COPD. In a hypobaric chamber at 2438 m, oxygen reversed the hyperventilatory response to hypobaric hypoxaemia.

Original BTS advice[1] was tested by Akerø *et al*,[7] who stratified 100 subjects with COPD using Sp_{O_2} assessed against HCT. In one-third of the subjects with sea level Sp_{O_2} >95%, their Pa_{O_2} fell during HCT to <6.6 kPa. Over two-thirds of those with sea level Sp_{O_2} 92–95% with an additional risk factor also had Pa_{O_2} values <6.6 kPa. The authors conclude that sea level Sp_{O_2} is not a reliable predictor of altitude Pa_{O_2} ≥6.6 kPa. An earlier study by Christensen *et al*[5] evaluated original BTS advice that sea level Pa_{O_2} >9.3 kPa precludes severe hypoxia at altitude.[46] Fifteen stable COPD subjects (mean±SD FEV_1 30.3%±11.6 predicted) were tested at sea level, 8000 ft (2438 m) and 10 000 ft (3048 m). Many developed marked hypoxaemia at 8000 ft and on exercise at altitude. The authors conclude that sea level Pa_{O_2} >9.3 kPa does not preclude hypoxaemia at altitude, and that neither resting nor exercise Pa_{O_2} at sea level predict hypoxaemia at altitude. Sea level aerobic capacity (V_{O_2}max) did, however, correlate with Pa_{O_2} at 8000 ft.

Since evidence for advising patients with COPD whether they can safely undertake commercial air travel is inconclusive, it is important to consider the outcomes of air travel in this group. Akerø[53] undertook in-flight assessment of 18 patients with COPD on a flight lasting 5 h 40 min with mean cabin altitude of 6000 ft. Stable patients with COPD were able to maintain stable arterial oxygen tensions. Kelly *et al*[92] studied 13 patients with COPD (7 women, mean±SD FEV_1 1.39±20%). They underwent pre-flight lung function tests (spirometry, static lung volumes and diffusion capacity) followed by in-flight measurement of Sp_{O_2}, heart rate and wrist altimeter, and a post-flight HCT and 6 min walk test (6MWT). During the flight there was significant hypoxaemia, worsened by exercise, but no adverse events. There was good correlation between HCT Sp_{O_2} and mean in-flight Sp_{O_2}, but no relationship between 6MWT and mean in-flight Sp_{O_2}. There was strong correlation between percentage predicted T_{LCO} and mean in-flight Sp_{O_2}, confirming that diffusion limitation is an important determinant of altitude-induced hypoxaemia.[86] Kramer *et al*[93] reported on 21 patients requiring lung transplantation or pulmonary thromboendarterectomy who were transferred by air with in-flight oxygen to a specialist centre, showing safety even in very severe disease.

The UK Flight outcomes Study,[6] a prospective multicentre observational study, examined outcomes of commercial air travel in patients with respiratory disease. Two hundred and forty-three (39%) had COPD (mild 2%; moderate 29%; severe 43%; very severe 26% according to GOLD[94] criteria). There were no in-flight deaths but one patient died within 4 weeks of returning. During the flight 18% of patients reported respiratory distress, mostly mild and manifest as worsening breathlessness. There was a relatively high need for antibiotics for respiratory tract infection within 1 month of travel. The authors concluded that commercial air travel is generally safe for patients under specialist respiratory care. Dillard *et al*[95] studied 100 patients with severe COPD (mean FEV_1 0.94), of whom 44 underwent air travel. Those who did not fly had a lower FEV_1 and greater home oxygen use. Of those who travelled, median flight duration was 3 h; eight reported transient symptoms with no adverse events. A retrospective study of 391 patients with COPD showed that 25% experienced hypoxia-related symptoms during air travel; symptoms were more frequent in those with more severe baseline breathlessness.[96]

Several studies report the incidence of in-flight medical emergencies. In a prospective study of emergency medical responses to travellers at Seattle-Tacoma Airport,[77] respiratory events represented 53 of 754 incidents (7%), COPD and asthma being the most common (8%). In a retrospective study by Delaune,[78] respiratory events comprised 11% of all events and caused 5% of diversions. A study for QANTAS in 1993 showed that respiratory events comprised 9% of all in-flight medical incidents.[79] The Paris Emergency Medical Service (SAMU) reported its provision of in-flight assistance to Air France[80] in 1989–99, recording 14/374 (3.7%) incidents of breathlessness with three requiring aircraft diversion.

Overall, the frequency of severe adverse events in patients with COPD who fly appears to be very low. Studies have used several variables to try and predict altitude-induced hypoxaemia. While some studies do show correlation between these variables and altitude-induced hypoxaemia, there is currently insufficient evidence on which to base clear recommendations using definitive cut-off levels of Sp_{O_2}, Pa_{O_2}, $FEV_{1.0}$, 6 min walk distance or other physiological variables. Lack of correlation between predicted arterial hypoxaemia in patients with COPD undertaking air travel and outcomes suggests that they tolerate hypoxaemia fairly well as a result of physiological adaptation.

Cystic fibrosis

- *In children with CF or other chronic lung diseases who are old enough for spirometry and whose FEV_1 is <50% predicted, HCT is recommended. If SpO_2 falls below 90%, in-flight oxygen is advised (C)*

Owing to the risk of cross-infection from other CF patients, the CF Trust strongly discourages group travel.

Several studies have examined the risk of hypoxia during exposure to ambient hypoxia in CF, in aircraft or at altitude and with or without exercise. A study in 22 children with CF[63] examined the incidence of hypoxia during HCT in the laboratory, in the Alps and on commercial aircraft, and all desaturated at altitude. HCT was found to be the best predictor of hypoxaemia at altitude. An earlier study[62] of 87 patients with CF aged 7–19 years who travelled on flights lasting between 8 and 13 h had suggested, in contrast, that spirometry was a better predictor of desaturation. The discrepancy may reflect the longer interval between HCT and flight, or the fact that in-flight measurements included some made during sleep. More recent studies by Peckham *et al*[97] and Martin *et al*[90] concluded that HCT results in individual CF patients could not be predicted reliably from spirometry, clinical scores or sea level blood gases.

Fischer and colleagues[98] studied a group of 36 patients with CF at rest and on exercise during a 7-h stay at an altitude of 2650 m. In these conditions, one-third of patients had P_{O_2} <6.6 kPa at rest, rising to two-thirds of patients with this level of hypoxia during mild exercise. The striking finding was that hypoxaemia was very well tolerated by the patients, with none reporting dyspnoea and only the most hypoxic patient (P_{O_2} 4.4 kPa) reporting some dizziness during exercise. Both spirometric measures and HCT predicted the majority of patients with altitude-induced hypoxaemia; however, HCT yielded a high false positive rate. Studies by Rose *et al*[99] and Kamin *et al*[100] using both hypobaric chamber and flight-induced hypoxia also confirmed that patients with CF do not usually report dyspnoea or other adverse symptoms, even when their P_{O_2} falls below 6.6 kPa.

Thus, patients with CF do become hypoxaemic at altitude but are rarely symptomatic. Those with a low FEV_1 (<50%) appear to be at increased risk of hypoxaemia, and HCT may yield further information. No study to date has shown a completely reliable method of predicting hypoxaemia at altitude.

Non-CF bronchiectasis

- *Nebulised antibiotics and nebulised bronchodilators should not be required (D)*

There are no published studies of hypoxaemia associated with air travel in patients with bronchiectasis. It is likely that the principles outlined above for CF will apply; however, objective evidence to guide practice is currently lacking.

Cancer

- *Severe or symptomatic anaemia should be corrected before travel, as should hyponatraemia, hypokalaemia and hypercalcaemia (D)*
- *Treatment (radiotherapy, chemotherapy and/or stenting) for major airway obstruction, including upper airways stridor, should be complete before travel and sufficient time passed to enable the physician to confirm stability (D)*
- *Patients with lymphangitis carcinomatosa or superior vena caval obstruction should only fly if essential, and have in-flight oxygen available (D)*
- *Pleural effusions should be drained as much as possible before travel (D)*
- *Patients with major haemoptysis should not fly (D)*
- *A doctor's letter is required for patients taking controlled drugs, giving patient details, return dates of travel, countries being visited and drugs being carried including doses and total amounts. The patient or carer should also consult the Home Office to determine local controlled drug importation rules* (http://www.homeoffice.gov.uk/) *(D)*
- *Neutropenic patients should be aware of the risk of infection (and its peak timing after chemotherapy) arising from close proximity to other passengers (D)*
- *Airlines do not allow patients to fly within 24 h of a seizure. The patient and carer should be aware that medical insurance is likely to be refused if the patient has cerebral metastases and that repatriation costs are significant (D)*

This section considers primary thoracic cancers and cancers which have spread to the lung, mediastinum or pleura; disease stages from post-diagnosis to active anticancer treatment, progressive and terminal disease; and long-term survivors. Although there is no specific literature addressing the challenges or outcome of air travel in these patients, the UK Flight Outcomes Study[6] included five patients with cancer, of whom one died within 4 weeks of returning home. The numbers are too small to draw firm conclusions, but overall mortality in this study was just 1%, suggesting that cancer patients merit careful specialist review if considering air travel. In the absence of evidence we have formulated advice which considers management of pain, dyspnoea and other key symptoms likely to impair the ability of patients to undertake air travel, as well as the practicalities of travelling across borders with controlled drugs including opiates.

Patients with cancer are living longer and, with less intensive chemotherapy regimens and new targeted treatments, are able to lead more normal lives. More cancer patients are keen to take overseas holidays, whether to European destinations or on long-haul flights. Some may travel abroad to seek medical, surgical or complementary treatments, often in advanced stages when conventional treatments available at home have been exhausted. Such patients may be systemically ill with potentially serious pulmonary complications.

The physician needs to consider the effects of cancer on pulmonary function and reserve, including thoracic muscle weakness, diaphragmatic weakness or paralysis; large airway obstruction; mediastinal lymphadenopathy; pleural disease and effusion, and other forms of thoracic cage fixation. Other issues include cough, haemoptysis, pain, fatigue, reduced mobility, biochemical abnormalities, cachexia and muscle deconditioning, seizures resulting from cerebral metastases and potential complications of anticancer treatment including neutropenic sepsis, bone marrow failure and pulmonary and cardiac reactions.

The main medical specialist may be an oncologist. However, as chest physicians are more familiar with respiratory physiology and appropriate investigations, communication between all relevant specialists and primary care is vital when planning air travel. Owing to the prothrombotic tendency of many cancers, there is likely to be an increased risk of venous thromboembolism (VTE). However, the magnitude of the increased risk is not quantified in the literature. Situations likely to impact on respiratory function and reserve are discussed below.

Patients with primary thoracic and secondary cancers are likely to suffer from dyspnoea; it is important to exclude correctable causes such as anaemia or reversible airflow obstruction. There are no published data to indicate the minimum haemoglobin level with which it is safe to fly, but

major airlines recommend that the haemoglobin level should be ≥8.5 g/dl before flying.

Patients with major airway obstruction are likely to have received radiotherapy and, in many cases, chemotherapy. Some will have an airways stent in situ. None of these preclude air travel, but sufficient time should have elapsed since anticancer treatment or stent insertion to allow the physician to confirm that the patient's condition is stable.

Patients with lymphangitis carcinomatosa are likely to be very breathless. Air travel should only be undertaken if essential, with in-flight oxygen available. Patients with superior venal caval obstruction usually have a poor performance status and are very symptomatic. Several factors may contribute to dyspnoea, including microembolisation from thrombus in the superior vena cava and concomitant mediastinal disease causing vascular and lymphatic obstruction. Air travel should only be undertaken if essential, with in-flight oxygen available.

Patients may have pleural and chest wall infiltration. The main consequence apart from pain (see below) is fixation of the thorax with reduced respiratory reserve. In-flight oxygen may be required; pleural effusions should be drained as much as possible before air travel.

Most patients with primary thoracic cancers have a degree of cough; a cough suppressant may be required for long flights. Productive cough should be treated appropriately with antibiotics and more than one course may need to be taken if staying overseas for a longer period. Patients with major haemoptysis should not fly.

Management of cancer pain is beyond the scope of this document. Specific issues relevant for patients planning air travel include the need for opiates, particularly Schedule A controlled drugs. These are morphine (excepting oramorph solution), oxycodone, hydromorphone, fentanyl, buprenorphine and methadone. Patients travelling within the EU should not experience difficulty, but the Home Office advises a standard doctor's letter to allow easy exit from the UK with controlled drugs. This should state the patient's name, address, date of birth, outward and return dates of travel, country to be visited and drugs carried, with doses and total amounts. The Home Office also advises those travelling abroad to contact the relevant Embassy/Consulate/High Commission regarding their policy on importing controlled drugs. The patient must understand that being able to take controlled drugs out of the UK does not automatically allow them to be taken into other countries. It is therefore advisable for the patient and/or carer to ascertain the local controlled drug importation rules beforehand; details are available from the Home Office (http://www.homeoffice.gov.uk/). Patients receiving opiate medication by patch delivery (fentanyl, buprenorphine) should be aware that sweating in hot climates may reduce patch adherence.

Some patients receive analgesics and antiemetics by continuous subcutaneous infusion through a battery-powered syringe driver. There are no published data on the effects of reduced atmospheric pressure on the dynamics of the pump mechanism, but they should not preclude air travel. Spinal drug delivery, either into the epidural or intrathecal space, using an external or preferably an implanted pump may in future become more common. With a fully implanted pump, the reservoir can be filled for several weeks. Despite a lack of data, it is not anticipated that reduced cabin pressure will significantly affect fully implanted devices. Patients with bone metastases may suffer considerable discomfort if required to sit in one position for prolonged periods and may wish to request aisle or bulkhead seating.

Many patients with cancer, even when apparently in remission, may suffer fatigue because of general debility and muscle deconditioning. Biochemical causes such as hyponatraemia, hypokalaemia and hypercalcaemia should be corrected before flying.

Patients receiving chemotherapy should be aware of the increased risk of infection and its peak timing, and ideally not fly until the risk of neutropenia has receded. Patients with advanced malignancy and extensive bone metastases, where there is generalised bone marrow failure and pancytopenia, are likely to be very ill and flying may not be advisable.

There are no specific airline policies or IATA regulations regarding cerebral metastases and seizures. Most major airlines will not carry a passenger within 24 h of a seizure but do not otherwise restrict air travel. Although cerebral metastases should not be affected by reduced pressure, moderate hypoxaemia at altitude could theoretically lower an already reduced seizure threshold. A common-sense judgement considering the patient's overall condition and the reason for flying is likely to be needed. The patient and carer should be aware that medical insurance is likely to be refused and repatriation costs significant.

Cardiac comorbidity

Exposure to acute hypoxia has multiple differential effects on the cardiovascular system.[101] In the systemic circulation, arterial hypoxaemia will induce vasodilatation—including of the coronary arteries—thus reducing systemic vascular resistance. Sympathetic activation increases cardiac output owing to an increase in heart rate and myocardial contraction velocity. The overall effect is either a fall or no change in systemic blood pressure. Conversely, alveolar hypoxia induces pulmonary vasoconstriction. At cabin pressure this effect will be mild in healthy passengers but may cause clinically relevant increases in pulmonary artery pressure in patients with existing pulmonary hypertension. The British Cardiovascular Society recently published guidance for air passengers with cardiac disease[30] but, since cardiac and pulmonary conditions often coexist and respiratory physicians are often consulted about HCT in cardiac patients, we feel it is appropriate to retain this section in our revised recommendations. Extra caution is advised, as significant falls in oxygenation on commercial aircraft may worsen cardiac disease.

Coronary artery disease

- *Patients who have undergone elective percutaneous coronary intervention can fly after 2 days (C)*
- *Patients at low risk after ST elevation myocardial infarction (STEMI)—namely, restoration of TIMI grade 3 flow on angiography, age <60, no signs of heart failure, normal ejection fraction and no arrhythmias—can fly after3 days (C)*
- *Other patients may travel 10 days after STEMI unless awaiting further investigation or treatment such as revascularisation or device implantation. (C) For those with complications such as arrhythmias or heart failure, advice in the relevant section below should be followed.*
- *Patients with non-ST elevation myocardial infarction (NSTEMI) should undergo angiography and revascularisation before considering air travel (C)*
- *Patients who have undergone uncomplicated coronary artery bypass grafting should be able to fly within 14 days but must first have a chest x-ray to exclude pneumothorax (C)*
- *Patients with stable angina up to Canadian Cardiovascular Society (CCS) functional class III are not expected to develop symptoms during commercial air travel (C)*

- *Patients with CCS functional class IV symptoms (defined as the inability to carry on any activity without discomfort), who may also get stable angina at rest, should be discouraged from flying. (C) If air travel is essential they should receive in-flight oxygen at 2 l/min and a wheelchair is advisable (C)*
- *Patients with unstable symptoms of ischaemic heart disease should not fly (D)*

The increased myocardial demand for oxygen on exposure to hypobaric hypoxia increases the potential for myocardial ischaemia when coronary arterial flow is restricted. Atherosclerotic coronary arteries may constrict in response to sympathetic activation[102] and, at 2500 m, patients with exercise-induced myocardial ischaemia have an 18% reduction in coronary flow reserve.[103] Most data suggest that clinically evident myocardial ischaemia will not develop at rest at the barometric pressures experienced in commercial aircraft.[101] One study showed that the ischaemic threshold was reduced by 5% in 20 subjects (mean age 68±3 years) taken acutely to an altitude of 2500 m. Half had exercise-induced ischaemia at sea level.[31] Consequently, most passengers should be able to exercise close to their sea level threshold for ischaemic symptoms during commercial air travel.

After acute coronary syndrome, the risk of air travel should be based on the sea level risk. Those at lowest risk are young patients in whom ST elevation myocardial infarction (STEMI) has been treated early with percutaneous coronary intervention with good demonstration of restoration of coronary blood flow (TIMI 3), no clinical evidence of heart failure, normal ejection fraction and no arrhythmias.[104] Patients with non-STEMI (NSTEMI) have a risk of recurrence and death, and decisions regarding air travel need to be made following a full risk assessment.[105] All patients without complications should be able to travel by air within 10 days.

Cyanotic congenital heart disease

- *Physicians should use their discretion in deciding whether to perform HCT and/or advise in-flight oxygen (D)*
- *Those in New York Heart Association (NYHA) functional class IV should avoid air travel unless essential. If flying cannot be avoided they should receive in-flight oxygen at 2 l/min (D)*

In cyanotic congenital heart disease an anatomical shunt enables a proportion of deoxygenated mixed venous blood to bypass the pulmonary circulation, leading to systemic hypoxaemia that cannot be corrected even with 100% oxygen. To maintain oxygen delivery, patients adapt to chronic hypoxaemia with rises in haematocrit and 2,3 di-phosphoglycerate. Patients should thus be iron replete in order to facilitate increased red cell synthesis.[106] Since not all mixed venous blood passes through the pulmonary circulation, the effect of hypobaric hypoxia on systemic oxygenation is less than in those with the same degree of desaturation due to lung disease. Physiological studies and surveys of patients with cyanotic congenital heart disease show that air travel is safe,[107 108] but self-selection may play a part in these results and they cannot be applied universally. Although not reported, it is likely that most patients were in New York Heart Association (NYHA) functional class I or II. A haemodynamic study in paediatric patients with congenital heart disease showed that a small number developed a pulmonary hypertensive crisis when 15% oxygen was given.[109]

Heart failure, valvular disease and pulmonary hypertension

- *Patients who are hypoxaemic at sea level, with coexistent lung and/or pulmonary vascular disease, should be considered for HCT (D)*
- *Patients in NYHA functional class I–III (without significant pulmonary hypertension) can fly without oxygen (C)*
- *Patients with severe disease in NYHA functional class IV should not fly unless absolutely essential. If air travel cannot be avoided, they should have in-flight oxygen at 2 l/min (C)*
- *Patients with pulmonary hypertension in NYHA functional class I and II can fly without oxygen (D)*
- *Patients with pulmonary hypertension in NYHA functional class III and IV should receive in-flight oxygen (D)*
- *Patients with valvular disease causing functional class IV symptoms, angina or syncope should use in-flight oxygen at 2 l/min if air travel is essential (D)*

Patients with chronic heart failure may experience worsened symptoms in a hypobaric environment owing to heightened underlying neurohormonal activation. Exercise capacity falls at increasing altitude, the extent depending on baseline functional capacity.[110] In patients with severe heart failure, peak work rate falls by 11% for every 1000 m ascended to 3000 m. Chronically elevated left atrial pressure may lead to 'passive' pulmonary hypertension, where pulmonary vascular resistance is normal, or 'reactive' pulmonary hypertension resulting from pulmonary vascular remodelling. In the latter, alveolar hypoxia is likely to be more detrimental to pulmonary hypertension and right ventricular function.

Patients with other forms of pulmonary hypertension (pulmonary arterial hypertension, chronic thromboembolic disease and lung disease) may suffer clinically significant increases in pulmonary vascular resistance resulting from hypoxic pulmonary vasoconstriction. If the right ventricle is unable to cope with the increased afterload, significant deterioration may occur. In contrast to other conditions affected by arterial oxygenation, pulmonary vasoconstriction results from alveolar hypoxia and oximetry does not predict the response of the pulmonary circulation to hypobaric hypoxia. Recommendations are therefore made on saturations and/or NYHA functional class as an indication of ventricular function.

Rhythm disturbance

- *Patients with unstable arrhythmias should not fly (C)*
- *Patients with high-grade premature ventricular contractions (Lown grade ≥4b) should be discouraged from flying but may fly at the physician's discretion with continuous oxygen at 2 l/min (D)*

Increased sympathetic activity associated with hypobaric hypoxia may decrease the arrhythmia threshold[111]; patients with severe underlying arrhythmias or high-grade premature ventricular contractions may thus be at increased risk. However, a review of 101 patients with chronic respiratory disease undergoing HCT showed that, in contrast to healthy individuals, acute hypoxia did not prolong cardiac repolarisation (QTc).[112] Modern pacemakers and defibrillators are compatible with aircraft systems.

Hypertension

- *Patients with severe uncontrolled hypertension should have it controlled before embarking on commercial air travel (D)*

Patients with systemic hypertension at sea level show an exaggerated sympathetic response when exposed to isocapnic hypoxia.[113] There are no data to evaluate the safety of such patients travelling on commercial flights, but it is possible that through this mechanism exposure to hypobaric hypoxia may cause clinical concern.

Hyperventilation and dysfunctional breathing

- *Patients with a diagnosis of hyperventilation, dysfunctional breathing and/or panic disorders should have full assessment before travel by a clinician skilled in managing these disorders, and*

appropriate breathing modification exercises and/or pharmacotherapy should be started before travel (D)

- *Where the cause of breathlessness on board is in doubt, oxygen should be given and skilled medical assistance obtained as soon as possible (D)*
- *Rebreathing techniques may be used on board for acute hyperventilation (D)*
- *Evaluation of response to rapidly acting anxiolytics is advised before travel (D)*

The literature is incomplete and many studies are old. Acute hyperventilation is dominated by respiratory symptoms[114]—particularly acute breathlessness—and may cause great alarm and distress to individuals, observers and flight crew.[115] Acute symptomatic hyperventilation may be triggered by emotion and stressful situations including air travel. Symptomatic hyperventilation has been highlighted as a problem in air crew[116] and passengers.[115] A high proportion of air crew under training exhibit hyperventilation in stressful flight situations.[117] Passengers subject to unusual stressors in flight such as emergencies may also hyperventilate.[118] Hyperventilation in response to stress is particularly common in people with pre-existing anxiety and panic disorders.[119]

There is very limited literature on the prevalence and implications of functional breathing disorders in relation to air travel. Acute psychiatric emergencies account for 3.5–5% of all in-flight medical emergencies[80 120]; 90% of these relate to acute anxiety episodes which may involve hyperventilation.[120] It has been suggested that a rapid-onset anxiolytic should be included in on-board medical kits.[80] It is also recommended that flight crews should be trained to recognise acute hyperventilation,[115 118] although distinguishing anxiety-induced hyperventilation from life-threatening acute medical conditions can be difficult. The challenges for air crew faced with an acutely anxious and over-breathing patient are considerable, and causes for rapid breathing and distress may include hypoxia, anxiety, hypoglycaemia and acute cardiac disease.[115] Where any doubt exists, supplemental oxygen should be given and medical assessment undertaken as soon as possible.[80] If hyperventilation and/or panic attacks are confidently diagnosed, rebreathing[118] and/or the use of a rapid-onset anxiolytic[80] have been advocated.

The assessment of fitness to fly in patients with dysfunctional breathing, hyperventilation or panic attacks has not been studied. Indeed, the diagnosis of 'hyperventilation syndrome'[121] or 'dysfunctional breathing'[122] can be taxing for clinicians. Recognition of symptoms during a period of voluntary hyperventilation has been advocated as a simple test to demonstrate the link between abnormal breathing and somatic symptoms,[121] some but not all of which relate to hypocapnia.[123] Breathing training exercises have been advocated as effective treatment for hyperventilation and panic;[124 125] it seems prudent for patients to have been taught and successfully used these techniques before flying. Where required, psychiatric assessment and treatment should be completed before travel. It has been suggested that people who regularly suffer anxiety attacks and hyperventilation when flying should take a sedative or anxiolytic before departure.[118]

Airborne infection

- *Pre-flight assessment is advised for those with acute and chronic respiratory infections (D)*
- *Patients with infectious tuberculosis (TB) must not travel by public air transportation. (C) WHO guidelines state that 'physicians should inform all infectious and potentially infectious TB patients that they must not travel by air on any commercial flight of any duration until they are sputum smear-negative on at least two occasions'. This may be overcautious. Patients in whom drug resistant TB is not suspected and who have completed 2 weeks of effective antituberculous treatment are in practice generally considered non-infectious.*[32]
- *Patients with multi-drug resistant TB (MDR-TB), extremely drug resistant TB (XDR-TB) or totally drug resistant TB (TDR-TB) must not travel by any commercial flight, whatever the duration, under any circumstances, until they are proven to be non-infectious with two consecutive negative sputum culture results (C)*
- *The latest web-based guidelines (national and/or international) should be consulted for travel restrictions regarding cases or contacts of patients with respiratory viral infections of high mortality such as severe acute respiratory syndrome (SARS). (D) This is especially important for any outbreak of an emerging respiratory infection. Updates are available on the WHO site* (http://www.who.int/)

The major concern for passengers regarding in-flight spread of respiratory infection is cabin air recirculation.[126] Air exchange rates on commercial airliners range from 20–30 changes per hour,[127] and 30–55% of air is recirculated. By contrast, 80% is recirculated in commercial buildings.[128] The air mixed with cabin air is taken from the external environment, which is sterile at high altitude and brought into the aircraft through the engines at very high pressures and temperatures.[129] Cabin air is routed through filters designed to extract droplet and particulate matter known as high efficiency particulate air filters (HEPA).[129 130] The ventilation system is designed to provide laminar air flow since air is introduced from the ceiling and removed from the floor by passengers' feet,[129 131 132] reducing longitudinal air flow along the cabin. Cabin humidity is kept low (5–15%) to prevent condensation on the aircraft's internal walls.

Respiratory pathogens usually spread by one of two routes—large droplets or airborne tiny droplet nuclei. Large droplets fall quickly to the ground, but tiny airborne droplets may disperse widely. The normal microbiological composition of cabin air on domestic and international flights is low[133 134] and less than that of normal city air.[135] HEPA filters are 99.9% effective at removing particles between 0.1 and 0.3 μm and 100% effective at removing other particles; bacteria are generally larger than this. Viruses tend to clump into airborne droplets around 5 μm. A study used an airborne tracer released into the passenger cabin of an aircraft cruising at altitude as a surrogate for release of an infectious agent. It showed that maximum tracer concentrations were 500 times greater at 2 m from tracer release than at 30 m where levels reached a maximum of just over 2 parts per billion volume.[136] HEPA filters were used on the flight but would not have filtered out the gas. These studies were all performed during 'normal' situations; it is unclear how this translates into real life—for instance, with a passenger with a highly infectious disease on board.

Tuberculosis

Active smear-positive tuberculosis (TB) is a highly infectious disease transmitted by airborne or (more often) large droplet routes.[137] TB is the most extensively investigated respiratory infection in the context of in-flight disease transmission. The prevalence of adults with active TB on long-haul air flights is estimated at 0.05 per 100 000 long-haul passengers.[138] In total, for flights over 8 h from 2000 to 2004, 34 cases of smear-positive TB were notified to airlines out of more than 68 million long-haul passengers; 5% were classed as highly infectious and 12% possibly drug-resistant. Fifteen per cent of these were known to be infectious or were under investigation before travel.

When restricting data to flights from endemic areas, the TB notification rate was 0.35 per 100 000 long-haul passengers. However, this paper estimated under-reporting of at least 15%. A further paper looked at all TB air travel-related incidents reported to the UK Health Protection Agency from January 2007 to February 2008.[139] Twenty-four cases were identified, of which 19 were smear positive; 75% of the cases flew on flights of >8 h. Two patients were later found to have multi-drug resistant tuberculosis (MDR-TB). In most cases further analysis was impossible owing to inadequate patient information.

There are few rigorous data on the transmission of TB on aircraft. The largest case series reported in a string of publications from 1992 to 1994 focused on six cases of active smear-positive highly infectious TB in five passengers and one member of the cabin crew.[140] Two of these cases had MDR-TB. Over 2600 passenger and cabin crew contacts were identified on several different flights. Evidence of TB transmission was reported in two publications. In the first the cabin crew contacts of a flight attendant with TB exposed over a 5-month period were given a tuberculin skin test (TST)[141]; 26% of those exposed when the index case was more infectious developed a positive TST compared with 4% of those exposed before the index case became infectious. Little evidence was found of transmission to passengers.

The second report detailed the results of contact tracing from a passenger with MDR-TB who had taken four long-haul flights while infectious and symptomatic.[70] Seven hundred and sixty out of a possible 1042 passengers were contacted. Of the 11 contacts with a positive TST on the first two flights, all had other risk factors for TB. However, on the third flight there was one contact and on the fourth flight six contacts with a positive TST with no obvious risk factors for TB; four of these had a documented conversion on repeat TST. All these contacts had sat in the same cabin section as the index case and four were seated within two rows. Using a similar contact tracing methodology, the other studies published in this series of infectious index cases on long-haul air flights did not document definitive evidence of transmission.[142 143]

In none of the above studies was transmission of clinically active TB reported. TB transmission was defined as a positive TST in the absence of any risk factors for TB. Associations with TB transmission included longer flights and seating in close proximity to the index case. These data suggest that, while in-flight TB transmission is possible, there is no greater risk of TB transmission during air travel compared with other modes of transport such as rail or bus,[144] or within office buildings.[145]

Several case reports have been published subsequently which provide little evidence for transmission of TB on aircraft. Laryngeal TB is thought to be more infectious than pulmonary TB. A report of an index case with laryngeal TB travelling on two short flights (<2 h) was published in 1996.[146] Of 161 possible in-flight contacts, only five were TST-positive and all had another risk factor for TB. In 1998 the pilot of a DC-9 aircraft was identified as having active TB.[147] In the preceding 6 months 48 pilots had flown with the index case and none showed any evidence of transmission by chest radiography or TST.

One study reported contact tracing from an index case with smear-positive active TB on a 14 h flight.[148] Eleven cases had documented TST conversions of which three were not accounted for by other risk factors. However, in contrast to previous case reports, these contacts were not seated in close proximity to the index case. A contact tracing study of a 21-year-old person with smear-positive active TB who travelled on two long-haul air flights while actively infectious reported 238 contacts on the two flights; serial TST results were available on 142.[149] Of 24 positive TST results, four were conversions (an initial negative TST followed by a positive TST several weeks later) and all had other risk factors.

A patient with extensively drug resistant tuberculosis (XDR-TB) travelled on a 5 h flight (Beirut to Paris) and died 10 days later.[150] The index case was smear-positive with a productive cough. Contact tracing was initiated despite the flight duration being <8 h because of the diagnosis of XDR-TB. Substantial obstacles to contact tracing were highlighted, including difficulty obtaining contact details, poor international cooperation and concerns over causing undue anxiety. The 11 close contacts identified were distributed worldwide and, by the publication date, only seven had been told of their contact status. No active TB transmission was discovered. The most recent (and most highly publicised) association of TB and air travel occurred in 2007 when a patient with presumed XDR-TB undertook several long-haul flights against medical advice.[151 152] No cases of TB transmission were identified.

Mathematical models have been used to estimate the risk of infection to passengers from an index case with TB.[153 154] The risk of infection depends on movement of the index case, effectiveness of ventilation and the amount of mixing of cabin air. A figure of 1:1000 has been proposed as the risk of TB transmission for exposed passengers.

The evidence thus suggests that the risk of TB transmission during air travel is low, and no higher than in any other confined space. Contact tracing is time- and resource-consuming[155] and, to date, no cases of active TB transmission have been documented despite numerous contact tracing investigations. Risk factors appear to be infectious TB, productive cough and smear-positive sputum, cavitating or laryngeal TB, flight time >8 h and proximity to the index case (within two rows).

Influenza

A large body of literature exists pertaining to international spread of influenza by air travel, particularly with reference to a pandemic.[156–161] Several authors have also examined whether air travel restrictions could mitigate pandemic influenza,[162–166] or whether quarantine of suspected cases at airports or borders is more effective.[167–169] Importation of influenza virus by air travel is well described.[170 171]

There are few data on in-flight transmission of influenza. In the first case series reported, a Boeing 737 with 54 passengers was grounded for 3 h in 1977 because of engine failure.[69] During this delay the normal ventilation system for the aeroplane was turned off. Most passengers remained on board and 38 (72%) later developed an influenza-like illness (ILI) with a median duration of 38 h. The presumed index case was a young adult with a severe cough throughout the flight. Eight of 31 passengers tested had the same strain of influenza A as the index case. As some passengers left the plane and some stayed in their seats, it was possible to show that the risk of ILI was related to time spent in contact with the index case (53% attack rate for <1 h on board compared with 86% for >3 h on board). Twenty-two of the symptomatic passengers had paired serum samples tested; 20 showed a significant rise in antibody titres to the relevant influenza strain.

The second case series involved an influenza outbreak at a naval air base in 1986.[172] Sixty of 114 squadron members developed influenza over a short period, of whom 24 developed ILI on return from an assignment in Puerto Rico. Twenty-three of 24 had travelled on a 2.5 h air flight on one of two DC-9

aircraft on which a squadron member who developed ILI before departure had also flown. Infection rates were fourfold different between the two aircraft. The authors concluded this probably reflected variation in infectivity of source patients and different numbers of source cases (three on the first plane and eight on the second).

A third case series was published in 2003.[173] A symptomatic index case with ILI boarded a 75-seat passenger aircraft on a 3.5 h flight. Over the next 4 days 15 people who travelled on the same flight developed ILI and a further six developed upper respiratory tract symptoms. Those affected were more likely to have sat close to the index case.

Influenza outbreaks during air travel do thus occur with symptomatic patients, probably via airborne droplet transmission. In the above cases the aircraft were either old or lacked functioning ventilation. This limits generalisation to modern well-ventilated aircraft and accounts for the stark difference in attack rates.

Severe acute respiratory syndrome (SARS)

SARS, caused by coronavirus infection, is characterised by fever, cough and breathlessness.[174 175] The two concerns pertaining to air travel are rapid dissemination of disease geographically and in-flight transmission. There is good evidence for significant disease spread via air travel during the 2003 SARS outbreak.[176–178] One paper describes six cases imported to Singapore in March and April 2003; four were rapidly identified and isolated on arrival and no secondary cases developed.[179] The other two cases were imported before the disease was recognised and substantial secondary spread was documented.

In-flight transmission of SARS appears uncommon. In-depth analysis of three flights on which a patient infected with SARS travelled occurred after the outbreak.[180] Three hundred and four travellers (45%) on the same planes were contacted and interviewed. Of these, 16 developed SARS and two probably developed SARS, but the possibility that transmission occurred before travel could not be excluded. Four of those not interviewed also developed SARS, with one other diagnosed as probable SARS. These 23 people were thought to spread SARS to at least 13 more subjects. Two of the three flights studied with five symptomatic patients resulted in only one additional patient being infected.

However, one flight with one infected symptomatic patient resulted in infection in 22 (18%) others on the flight. During this flight the risk of contracting SARS was greatest for those on the same seating row or three rows in front of the index patient, although substantial numbers of patients who contracted SARS from that flight were seated further away or behind the index case, suggesting that spread may be airborne rather than large droplet. All patients infected were in the same section of the aircraft, indicating that the ventilation system was not responsible for transmission.

One study examined nine cases of SARS on seven flights to Singapore.[181] Of these, four patients on three flights were symptomatic and only one case of in-flight transmission was documented. This patient had significant respiratory symptoms (cough), in contrast to some others with fever alone. Transmission was from an index case to a flight attendant despite minimal contact, the attendant never coming within 1 m of the passenger isolated at the rear of the plane with suspected SARS.

One study examined the transmission of SARS by an index patient who had travelled on seven European flights.[182] The patient was symptomatic during all but one flight. Two hundred and fifty contacts were identified but only 36 were included in the study. SARS serology was negative in all of these. Ten described post-flight symptoms such as cough, headache and myalgia, but none developed proven disease. Finally, contact tracing studies of patients with SARS flying to Canada[183] and the USA reported no SARS cases linked to in-flight transmission, even in symptomatic patients with contacts seated in close proximity.

In-flight transmission was therefore probably low for most patients with SARS. However, certain patients ('super-spreaders') seem to generate high rates of transmission, predominantly those who were symptomatic, and particularly those with respiratory symptoms.

Common cold

Many air travellers complain of symptoms attributed to infection after air travel, such as dry eyes and throat, headache, fatigue and nasal stuffiness.[127 184 185] There is little convincing evidence that such symptoms reflect infection. Robust data on the prevalence of respiratory viruses or bacteria in patients complaining of upper respiratory tract symptoms are not available. A study testing respiratory samples from 172 patients with suspected SARS after air travel found a broad range of respiratory viruses and atypical pathogens in 43% of subjects.[186] Pathogens included parainfluenza and influenza (most common), adenovirus, coronavirus, rhinovirus, meta-pneumovirus and respiratory syncytial virus, as well as bacteria such as *Legionella* and *Mycoplasma*.

Transmission was not identified between passengers and 'clumping' of cases with the same pathogen by seating pattern was not evident. A study of patients attending airport medical facilities in Oman showed that 19.7% were diagnosed with upper respiratory tract infection but the authors do not detail how the diagnosis was made.[187] None were later hospitalised and no cases of lower respiratory tract infection or pneumonia were reported. One study compared the incidence of upper respiratory tract infection between passengers on flights where the air is recirculated and those where the air is fully imported from the external environment.[188] Similar levels of symptoms were seen in both groups, suggesting that air recirculation does not increase transmission of upper respiratory tract infection.

One study reported that increasing in-flight humidification can alleviate many such symptoms.[18] Flight attendants are more likely to report work-related upper respiratory tract infections including colds and influenza than the general population, but not more so than school teachers.[189] Upper respiratory symptoms experienced during flying and attributed to infection may thus be at least partly due to reduced partial pressure of oxygen, jet lag, noise, vibration, low humidity and other stressors.[130]

Community-acquired pneumonia

Few data are available on the safety of air travel for patients with community-acquired pneumonia (CAP). Data from emergency air medical transport cases show that, despite emergency repatriation of several patients with CAP, no deaths or adverse events were reported in flight.[190] A study of cases for which medical assistance was required on British Airways flights from January to September 2000 found that around 5% were respiratory; no cases of CAP were reported.[29] In a series of nine patients returning by air from abroad with CAP who were symptomatic on board, only one was being medically evacuated and no in-flight adverse events were reported in the others.[191] Other data have shown that about 6.9% of pre-flight oxygen assessments are made for patients who have had CAP in the preceding month.[192] Current advice is that patients should be

afebrile and sufficiently clinically stable to tolerate air travel and minimise transmission of communicable infection to other passengers.[20 193] Significant hypoxia would also preclude air travel.

Lung abscess

There are no published data on the effects of air travel on patients with lung abscess. Concerns are the same as for patients with CF and/or bronchiectasis—namely, to maintain adequate hydration, access to medication and adequate oxygenation before departure.

In summary, hypobaric hypoxia is the main risk to patients with chronic or acute respiratory infections.

HIV infection

- *HIV-positive passengers should check with the embassies of the countries they are visiting for visa requirements or travel restrictions (D)*
- *General measures help minimise the risk of exposure to blood-borne viruses and are appropriate for all settings where passengers are bleeding, whether or not they are HIV-positive. (C) Extensive guidance on such measures is available from the UK Department of Health* (http://www.dh.gov.uk/*)*
- *Some HIV-positive passengers are at risk of developing opportunistic infection (OI). Patients are usually not deemed fit to travel during the acute phase of an OI (D)*
- *The physician caring for the patient should advise whether a patient who has been treated for a specific OI is fit to travel based on their clinical condition and patient needs. (D) Airline guidance should also be sought*
- *Advice on pre-flight vaccination is available as part of current British HIV Association guidelines*[33] (http://www.bhiva.org/*) (D)*
- *Patients should carry a supply of antiviral drugs and other medication in hand luggage. If they forget to take their antiviral dose they should take their next dose as soon as practical and then revert to their normal schedule (D)*

There is no literature specifically addressing the risk of air travel for patients with HIV or other blood-borne viruses. It is clearly vital to protect airline staff and other passengers from infection, and there is ample information on the risk of contracting HIV from body fluids. HIV is not present in urine, faeces, vomit and sweat. It is present in tiny but non-infectious quantities in saliva, tears and blister fluid. However, these fluids are potentially infectious if frankly blood-stained. HIV is present in infectious quantities in blood and blood products, genital secretions (including semen) and breast milk.

Although data suggest that HIV-positive patients with TB may be less infectious than HIV-negative patients,[194–198] this should not be assumed to be true for air travel. HIV-positive patients with infectious TB must not travel. The passenger with HIV exposed to sputum-positive TB may, if infected, have a 50% greater risk of progression to active disease (and greater lifetime risk) depending on their CD4 count.[198–200]

Interstitial lung disease (ILD)

- *Patients should be carefully assessed as previously described (D)*
- *Oxygen should be considered for those staying at high altitude destinations (D)*
- *An emergency supply of antibiotics with or without prednisolone is prudent, together with medical advice on managing steroid dose during intercurrent illness if the patient is already taking oral corticosteroids (D)*

Data remain limited. Kramer and colleagues reported on six patients with pulmonary fibrosis flown to specialist centres for single lung transplantation.[93] Resting sea level Pa_{O_2} ranged from 5.3 to 7.3 kPa and FEV_1 from 23% to 68% predicted. All patients flew with in-flight oxygen (4–8 l/min), four had a medical escort and flight duration ranged from 4.5 to 20.5 h. All arrived safely without complications. During a study of hypobaric hypoxia in patients with restrictive lung disease, Christensen *et al*[201] examined 10 patients with lung fibrosis (three with sarcoidosis, two with fibrosing alveolitis and the remainder unspecified fibrosis). All had FEV_1 around 50% and total lung capacity <80% predicted. At simulated altitude, Pa_{O_2} fell significantly and fell further during light (20 W) exercise, equivalent to slow walking along the aircraft aisle. Supplementary oxygen restored Pa_{O_2} to acceptable levels.

Seccombe *et al*[202] evaluated the effect of simulated cabin altitude on 15 patients with ILD (11 men) and 10 with COPD at rest and during a limited (50 m) walking test. Even with acceptable resting sea level arterial blood gas tensions, significant desaturation occurred in both groups (mean Sp_{O_2} 87% and mean Pa_{O_2} 6.8 kPa in patients with ILD) which worsened with minimal exercise (mean Sp_{O_2} 79.5% and Pa_{O_2} 5.5 kPa in ILD). Resting blood gas determinations at rest did not predict subsequent hypoxaemia. This finding is consistent with the UK Flight Outcomes Study, a prospective observational study of 431 patients (including 186 with ILD)[6] which showed that neither FEV_1 nor resting Sp_{O_2} predict desaturation at altitude. Patients with ILD were more likely than others to require unscheduled healthcare for respiratory events within 4 weeks of air travel. There were no documented episodes of VTE in this period, but 65% of all patients requiring unscheduled healthcare (irrespective of diagnosis) reported receiving antibiotics for lower respiratory tract infection.

Martin *et al*[90] included 15 patients with ILD in a study comparing HCT with predictive equations; predictive equations overestimated the need for in-flight oxygen in patients with ILD as well as those with COPD and CF. In a study examining the effects of oxygen on sleep and breathing in patients with ILD living at 2240 m in Mexico City (and thus acclimatised to moderate altitude), no difference in sleep efficiency or arousal index was observed between patients and controls.[203] Oxygen reduced heart rate and breathing frequency in patients during sleep but did not normalise breathing frequency.

In conclusion, patients with ILD should be evaluated as previously described since, at present, there are insufficient data to justify changes to pre-flight evaluation. Patients staying at high altitude destinations will experience desaturation and tachypnoea; their significance is currently unclear but supplementary oxygen may need to be considered. Patients with ILD appear relatively likely to require emergency medical care after air travel. They should therefore be carefully assessed beforehand for coexisting morbidities and their risk of respiratory tract infection, which may justify an emergency supply of antibiotics with suitable medical advice.

Neuromuscular disease and kyphoscoliosis

- *All patients with severe extrapulmonary restriction, including those needing home ventilation, should undergo HCT before travel (C)*
- *The decision to recommend in-flight oxygen and/or non-invasive ventilation must be made on an individual clinical basis (D)*

Data remain sparse. There is one case report of cor pulmonale developing in a patient with congenital kyphoscoliosis after intercontinental air travel.[204] The patient was a 59-year-old man with apparently stable cardiorespiratory function who developed a first episode of pulmonary hypertension and right heart failure after a long-haul flight. The authors concluded that this

resulted from prolonged exposure to a reduced Fio_2 in the aircraft cabin.

A recent study[205] examined 21 patients (16 with idiopathic kyphoscoliosis and five with neuromuscular disease). Thirteen were male and the median age was 58 years (range 22–73). Median FVC was 0.81 l (range 0.3–1.2) and median FEV_1 was 0.66 l (range 0.3–1.0). Median Spo_2 at sea level was 95% (range 92–99%). Fifteen patients were domiciliary NIV users. All patients underwent standard HCT. In six patients with resting Spo_2 >95% on air and in five with resting Spo_2 92–95%, Pao_2 fell to <6.6 kPa on HCT.

Desaturation on HCT was likely if FVC was <1 litre, even with resting sea level Spo_2 >95%. There is still no evidence as to whether this level of hypoxaemia has adverse effects, and no data exist to support either non-invasive ventilation (NIV) or supplemental oxygen as the best approach for such patients when flying. The authors conclude that all patients with severe extrapulmonary restriction should undergo HCT before air travel, and that the decision to recommend in-flight oxygen and/or NIV should be made on an individual basis, taking into consideration previous travel history, clinical condition and HCT results.

Obstructive sleep apnoea syndrome (OSAS)

A doctor's letter is required outlining the diagnosis and necessary equipment. It should state that the CPAP machine should travel in the cabin as extra hand luggage (some airlines treat this as excess luggage). A fact sheet for passengers to show airport security personnel is available from the American Sleep Apnea Association (http://www.sleepapnea.org/)

- *Alcohol and sedatives should be avoided before and during travel (D)*
- *A/C power is not usually available on board and passengers should use dry cell batteries; dry cell battery-powered CPAP can be used throughout except during take-off and landing (D)*
- *CPAP machines used in-flight should be capable of performing adequately in the low pressure cabin environment (D)*
- *Patients should ensure that their CPAP machine is compatible with the altitude and power supply at their destination, and that a power supply is within reach of the bed (D)*

Little is known about the effects of air travel on patients with obstructive sleep apnoea syndrome (OSAS). Patients are advised to avoid alcohol before and during flight because of the adverse effects of alcohol on sleep and OSA.[206] Sleeping tablets and sedatives should also be avoided.[207] Flights may be scheduled overnight; many patients with OSAS report that if they fall asleep their snoring disturbs neighbouring passengers. Patients may wish to drive or work soon after overnight flights; evidence suggests that withdrawing CPAP for just 1 day may cause sleepiness.[208] After transmeridian flights patients may also suffer from jet lag. It therefore seems advisable for patients to use CPAP while sleeping in-flight (having notified the airline in advance), but this usually requires power from a suitable battery. Power supplies are not available on all flights, sockets may not be available at every seat and, even if available, not all airlines allow them to be used for such equipment. Airlines do not always provide an appropriate adaptor and older machines may not be compatible with the power supply. Some CPAP machines can be powered from a direct current while others require an inverter. Dry batteries are heavy and will only power a CPAP machine for a limited time. Obtaining advice from airlines can been difficult and patients have even been prevented from flying.[209]

CPAP use in flight and at high altitude destinations requires a machine that will perform adequately at low ambient pressure. Calculations based on the collective fan laws and measurements made in a hypobaric chamber have shown that a fixed-pressure CPAP machine without pressure compensation set to deliver a pressure of 12 cm H_2O at sea level may deliver only 9 cm H_2O at 8000 ft. Machines with pressure sensors can deliver accurate pressures across a range of pressure/altitude combinations. Patients should use their CPAP machines at their destination as at home; adaptors and extension cables may be required.

Obesity

- *Obese passengers may have difficulty fitting into standard airline seats and should check in advance with the airline that one seat is sufficient (D)*
- *Those with a BMI >30 kg/m^2 should be considered at moderately increased risk of VTE and follow advice for those travelling for >8 h (D)*

The prevalence of obesity is rising in developed countries and its association with OSAS is well-known. Obesity may also cause dyspnoea, chronic hypoventilation (obesity hypoventilation syndrome), complicate COPD (overlap syndrome) and is a risk factor for VTE. Within the UK, patients are now increasingly making short flights to and from major centres for bariatric surgery; whether this presents a risk is unknown. There are few data on the effects of air travel in obese subjects; there is one case report of a morbidly obese woman who developed respiratory and cardiac failure after a 2-week tour involving two flights and a stay at altitude.[210]

Pneumothorax

- *Patients with a closed pneumothorax should not travel on commercial flights (with the exception of the very rare case of a loculated or chronic localised air collection which has been very carefully evaluated) (C)*
- *Patients who have had a pneumothorax must have a chest x-ray to confirm resolution before flight. Many would regard it as prudent for a further 7 days to elapse before embarking upon flight (C)*
- *In the case of a traumatic pneumothorax, the delay after full radiographic resolution should preferably be 2 weeks (D)*
- *A definitive surgical intervention undertaken via thoracotomy is likely to be entirely successful and patients should be allowed to fly once they have recovered from the effects of their surgery. (D) A similar intervention undertaken by video-assisted thoracoscopic surgery will also be expected to have a high success rate but cannot be regarded as definitive, and these patients should be aware of a slight risk of recurrence (B)*
- *Patients having other forms of attempted pleurodesis and those not undergoing attempted pleurodesis after a previous pneumothorax are unlikely to have further episodes precipitated by flight; however, spontaneous recurrence could have significant consequences in the absence of prompt medical care. The risk of recurrence is higher in those with coexisting lung disease and does not decline significantly for at least 1 year. Those not undergoing a definitive surgical procedure may therefore wish to consider alternative forms of transport (D)*
- *Patients with lymphangioleiomyomatosis should be advised that they are at increased risk of pneumothorax and that any unusual clinical symptoms such as chest pain or breathlessness should preclude air travel until fully evaluated (D)*

Flying with an untreated pneumothorax presents a risk because pressure changes during ascent can cause expansion of the air in the pleural space between the visceral and parietal pleura. Data from the BTS UK Flight Outcomes Study[6] have provided more information regarding the safety of air travel for those with lung

disease and, despite a high proportion of patients flying with COPD, no pneumothoraces were reported. Similarly, no pneumothoraces were reported in a retrospective study of 10 189 cases of surgical and medical emergencies on board European aircraft.[12] A 'new' pneumothorax occurring at altitude may be hazardous because of the absence of medical care, but flying does not make a pneumothorax more likely.

The key issues to address are the likelihood of a pneumothorax occurring spontaneously in someone with pre-existing lung disease and the likelihood of recurrence after a previous pneumothorax. In order to determine an optimal time for air travel after a documented pneumothorax, the literature was reviewed to determine recurrence rates without treatment or after an attempted definitive procedure.

In the 2002 BTS air travel recommendations[1] it was noted that, if the pneumothorax had been treated by thoracotomy and surgical pleurodesis or by talc insufflation (at thoracotomy), the recurrence rate should be so low that no subsequent restriction on travel is necessary. At that time a note of caution was inserted to the effect that similar interventions undertaken via thoracoscopy may not always carry the same certainty of success.[211–214] A more recent systematic review of both randomised and non-randomised trials has confirmed these earlier individual trials in showing a very high success rate with pleurodesis undertaken via open surgery, but up to four times higher rate of recurrence in those having a video-assisted thoracoscopic procedure.[215] While video-assisted thoracoscopic interventions may have other advantages in cases of recurrent pneumothorax, advice regarding future risk should take into account the fact that the definitive nature of the intervention is more certain if it is undertaken via an open surgical procedure.

Chemical pleurodesis not using talc (eg, with tetracycline) inserted without direct vision (thoracoscopic or surgical) is associated with a much higher risk of recurrence: 16% in one study with 50% of recurrences arising at 30 days,[216] and 13% in another.[213] The best figure was 9% rate of recurrence after chemical pleurodesis[217]; these data suggest that, even after such an intervention, the patient should still receive travel advice.

For patients who have not had a definitive surgical pleurodesis via thoracotomy, a risk of recurrence should thus be expected. If they have had an intervention using video-assisted thoracoscopy they should be advised of a very low rate of recurrence. A definite risk of recurrence should be expected in all other patients. While many studies have included details of the percentage of patients suffering a recurrence, very few give details of the timing of recurrence and few have characterised those most at risk. In one study a 54.2% recurrence rate was recorded with most occurring within 1 year[218]; in another study 72% of recurrences occurred within 2 years of the first episode.[219]

Cumulative freedom from recurrence data have been published by Lippert[219] and stratified according to smoking history and underlying lung disease over a follow-up period of up to 13 years. The shape of the curve (see figure 3, Appendix 7) does not imply that the biggest risk of recurrence is only in the first year. Furthermore, current advice does not take into account those with a higher risk of recurrence such as smokers, those with pre-existing lung disease, taller men and possibly women.[219 220] Thoracoscopic examination of the pleura does not improve prediction of those at greatest risk of recurrence.[221]

In practice, commercial airlines routinely fly patients on scheduled flights safely within 1 week of resolution of spontaneous pneumothorax on chest radiography. However, one study of 12 consecutive patients wishing to fly after recent traumatic pneumothorax showed that 10 waited at least 2 weeks after radiological resolution and were asymptomatic during flight. One of two patients who flew within 14 days developed distress during flight.[222] We therefore recommend, as previously,[2] a delay of 1 week after chest radiographic resolution where the pneumothorax is spontaneous and a delay of 2 weeks where it is traumatic.

A different dilemma is presented by patients with residual small or loculated pneumothoraces which have been present for some time. Two case reports of investigations and outcomes in such patients were found. These were extensively investigated without problems and/or tolerated HCT without adverse events. The authors concluded that some patients with a closed chronic pneumothorax can fly without adverse consequences. However, these may not have been typical patients. They may have had spontaneous or surgically-induced adhesions over much of the pleural surface and they only flew after extensive investigations had confirmed the stability of their condition.[223]

Patients with pulmonary lymphangioleiomyomatosis (LAM) are prone to pneumothoraces, and a questionnaire survey of women listed on USA and UK LAM registries has been published.[224] Two hundred and seventy-six respondents had travelled by air and 10 had suffered a pneumothorax, of whom eight had the diagnosis confirmed by chest x-ray. The patients who reported a pneumothorax in association with air travel were asked for further information. Eight of the 10 women had at least one prior pneumothorax; one respondent had developed a pneumothorax on two separate flights. The authors estimate the risk of a pneumothorax in flight to be 2.2% (10 pneumothoraces during 454 flights) and the risk estimate of pneumothorax per woman flying was 4% (10 women with pneumothoraces among 276 women who flew). Half of those who suffered a pneumothorax had symptoms to suggest that it might have been present before boarding the flight and, in four cases, the symptoms began on board or after landing. These authors, while recognising the limitations of their methodology, recommend that patients with LAM should be advised that the presence of any clinical symptoms such as unusual chest pain or shortness of breath should preclude flying until fully evaluated. However, since pneumothorax is relatively uncommon in patients with LAM, they do not believe that LAM should preclude air travel.

Pulmonary arteriovenous malformations (PAVMs)

- *Patients with PAVM with or without significant hypoxaemia should be considered at moderately increased risk of VTE (D)*
- *Patients with PAVM with a previous VTE or embolic stroke should receive a single dose of low molecular weight heparin before the outward and return journeys (D)*
- *Patients with PAVM with severe hypoxaemia may benefit from in-flight oxygen (D)*
- *For patients with PAVM with a previous VTE or embolic stroke in whom embolisation treatment is planned, deferring long-haul non-medical flights may be advisable until embolisation is complete (D)*

Pulmonary arteriovenous malformations (PAVMs) provide direct capillary-free communications between the pulmonary and systemic circulations.[225] Pulmonary arterial blood passing through these right-to-left shunts cannot be oxygenated, leading to hypoxaemia. Furthermore, the absence of a filtering capillary bed allows particulate matter to reach the systemic circulation; embolic strokes are thus a common complication. The majority of PAVMs occur in individuals affected by the inherited vascular disorder hereditary haemorrhagic telangectasia (HHT)[226] in

which additional prothrombotic states (particularly elevated factor VIII) may be present.[227]

From first principles, concern regarding in-flight exacerbation of hypoxaemia would appear justified as well as concern regarding the increased risk of VTE, with the added risk of paradoxical embolic strokes. However, patients with PAVMs frequently tolerate severe hypoxaemia without ill effect and, owing to the right-to-left shunt, increased Fi_{O_2} will have a lower proportional effect than in other patients.

There are no published data on air travel and hypoxaemi, and no data to indicate a threshold Sp_{O_2} or Pa_{O_2} which would predict the need for in-flight oxygen. Anecdotal experience is that individuals with profound hypoxaemia (resting Sp_{O_2} at sea level <80%) have flown without oxygen without seeking medical advice and suffered no ill effects. No data on flight-associated complications in patients with PAVM or HHT were identified through a Medline search. However, one of a series of cases of VTE among patients with PAVM/HHT[227] and one of a series of cases of paradoxical embolic stroke among patients with PAVM/HHT[228] occurred immediately after transatlantic flights.

Sinus and middle ear disease

- *Adults with risk factors for sinus or middle ear barotrauma (mucosal oedema, bacterial infection, thick mucin, intrasinus and extrasinus pathology and tumours) should receive an oral decongestant before travel and a nasal decongestant spray during the flight just before descent (D)*
- *Women in the first trimester of pregnancy may wish to take intranasal steroids instead of topical decongestants (D)*
- *Passengers who develop sinus barotrauma after flying should receive topical and oral decongestants, analgesics and oral steroids (D)*
- *Antibiotics are advised if bacterial sinusitis is thought to be the trigger, and antihistamines if allergic rhinitis is suspected (D)*
- *Symptoms and signs of barotrauma should have resolved before flying again; some recommend plain radiography to ensure that mucosal swelling has settled. This usually takes at least a week and may take up to 6 weeks (D)*
- *Recurrent sinus barotrauma is usually only seen in military air crew and has been shown to respond to functional endoscopic sinus surgery (D)*

Sinus barotrauma occurs when pressure in the sinuses cannot equilibrate with the environment owing to occlusion of the sinus ostium.[229] It can occur on ascent (known as reverse squeeze) or descent (known as squeeze); problems on descent are twice as common. Risk factors for squeeze are mucosal oedema, pus, thick mucin, extrasinus polyps and tumours. Risk factors for reverse squeeze also include intrasinus pathology. Air escaping via a non-physiological route with reverse squeeze can have serious consequences including subcutaneous or ocular emphysema, blindness, pneumocephalus, meningitis and trigeminal dysfunction.[230] Children are at particular risk of barotrauma.

The risk of sinus barotrauma is increased by a higher rate of change of altitude. Commercial air travel does not usually expose passengers to a faster descent than 100–120 m/min, so any sinus barotrauma is likely to be mild. Sinus barotrauma has been classified by Weissman and Garges (see Table 3).[231] More severe types are more likely in military pilots.

Presentation in civilian passengers is usually with frontal sinus pain, but bloody discharge has been reported. More severe sinus barotrauma in air crew also usually presents with frontal pain, but there may be malar pain and bloody rhinorrhoea. The mucosa may tear from the periosteum causing haematoma formation.[232]

Table 3 Classification of sinus barotraumas

Class	Symptoms	Radiography	Pathology
1	Transient discomfort	Normal	Slight swelling
2	Pain <24 h	Mucosal thickening	Serosanguinous rhinorrhoea
3	Severe pain	Obliterated sinus	Haematoma, mucosal avulsion

There are no controlled trials in passengers at risk of sinus barotrauma, but there is evidence to support prophylactic treatment for adults at risk of middle ear barotrauma. An oral decongestant beforehand and a nasal decongestant spray during the flight just before descent are recommended in both situations.[229 233] In contrast, a randomised controlled trial of pseudoephedrine given pre-flight to children with ear pain or nasal congestion did not show any benefit.[234] Patients in the first trimester of pregnancy may wish to avoid topical decongestants and take nasal steroids instead. A small study of air travel in children with otitis media did not show that air travel increased symptoms or later complications,[235] perhaps because the middle ear was filled with fluid and not air.

Treatment for sinus barotrauma after the flight is usually topical and oral decongestants, analgesics and oral steroids. Antibiotics are used if a bacterial sinusitis is thought to be the trigger and antihistamines if allergic rhinitis is suspected. All symptoms and signs of barotrauma should have resolved prior to flying again, and some recommend plain radiography to ensure that mucosal swelling has settled. This usually takes at least a week and can take up to 6 weeks.[236] Recurrent sinus barotrauma is usually only seen in military air crew and has been shown to respond to functional endoscopic sinus surgery.[237]

In conclusion, there is limited evidence on which to base recommendations. However, mucosal oedema caused by upper respiratory tract infection or allergic rhinitis probably increases the risk of sinus barotrauma. Topical decongestants before the flight and nasal decongestant spray prior to descent are currently recommended for adults at risk, but not for children. Severe barotrauma is unlikely in passengers due to the low pressure differentials and slow rates of change in cabin altitude.

Thoracic surgery

- *In patients who have undergone thoracic surgery with drain insertion, chest radiography is required after drain removal to ensure full expansion of the lung (C)*
- *Patients who have a pneumothorax after drain removal should not travel on commercial flights until full re-expansion has been confirmed on chest radiography (C)*
- *If chest radiography after drain removal confirms full re-expansion, it is prudent to wait for 7 days before embarking upon air travel (D)*
- *Any symptoms or signs suggesting the possibility of a pneumothorax after drain removal should prompt a further chest x-ray before air travel (C)*

There is no direct evidence to guide recommendations for air travel in patients who have recently undergone thoracic surgery. Indirect evidence is largely extrapolated from small studies of pneumothorax and air travel, as reviewed above.

A pneumothorax is universal during intrathoracic surgery and the risk of persistence depends on a number of factors. With regard to the surgical procedure, procedures that breach the visceral pleura (eg, pulmonary resection) have a higher risk of air leak than those that do not breach the visceral pleura (eg, resection of mediastinal tumours and pleural biopsies). Another potential for postoperative pneumothorax development is

introduction of air into the pleural space when drains are removed. Owing to the lack of data to support decision-making after surgery, we have made our recommendations consistent with those for pneumothorax.

VTE for flights >8 h or multiple shorter journeys over a short period

Low risk for VTE: all passengers not in the categories list below.

- *Passengers should avoid excess alcohol and caffeine-containing drinks, and preferably remain mobile and/or exercise their legs during the flight (D)*

Moderately increased risk of VTE: family history of VTE, past history of provoked VTE, thrombophilia, obesity (BMI >30 kg/m^2), height >1.90 m or <1.60 m, significant medical illness within previous 6 weeks, cardiac disease, immobility, pregnancy or oestrogen therapy (including hormone replacement therapy and some types of oral contraception) and postnatal patients within 2 weeks of delivery.

- *These patients should be advised to wear below-knee elastic compression stockings in addition to recommendations for low-risk passengers. In addition, they should be advised against the use of sedatives or sleeping for prolonged periods in abnormal positions. (D) Passengers with varicose veins may be at risk of superficial thrombophlebitis with use of stockings; the risk/benefit ratio here is unclear*

Greatest increased risk of VTE: past history of idiopathic VTE, those within 6 weeks of major surgery or trauma, and active malignancy.

There is no evidence to support the use of low or high-dose aspirin.

- *Pre-flight prophylactic dose low molecular heparin should be considered or formal anticoagulation to achieve a stable INR between 2 and 3, for both outward and return journeys, and decisions made on a case-by-case basis. The recommendations are in addition to the general advice for those at low to moderate risk (D)*
- *Patients who have had a VTE should ideally not travel for 4 weeks or until proximal (above-knee) deep vein thrombosis has been treated and symptoms resolved, with no evidence of pre- or post-exercise desaturation (D)*

In 2001 the WHO concluded that there was a likely association between air travel and increased risk of VTE. It identified key areas for research, in particular to confirm and quantify the risk, to determine the interactive effect of other risk factors and to understand the underlying mechanisms. Lastly, there was a need to assess the impact of preventive strategies. Since then many studies have attempted to address these questions, most notably those which made up the WRIGHT Project (WHO Research Into Global Hazards of Travel) commissioned by WHO.[238]

These studies were reviewed and published in the WRIGHT project report.[238] They comprise case-control studies which provide an estimate of RR, and cohort studies which give estimates of absolute risk. The data suggest an overall doubling of risk of VTE after long-haul air travel (>4 h). This risk can also be applied to other forms of travel such as bus, train or car. Risk increases with duration, with a fourfold increased risk on journeys >8 h. Multiple short journeys over a short period are also associated with an increased risk. Using screening, the absolute risk of developing asymptomatic VTE ranges from 0 to 10%.[239–243] The absolute risk of symptomatic VTE is much lower at around 1 in 4600, rising to 1 in 1200 for journeys >16 h.

Pulmonary embolism after long-haul flights often presents earlier, on standing up or in the airport, and may be fatal. This probably explains why VTE has received so much media attention and raised concern among the public. The risk of presenting acutely with pulmonary embolism after a long-haul flight of <8–9 h remains very low (<0.5 per million), but rises to five cases per million in flights >8–9 h.[244] A recent study has shown that the risk of pulmonary embolism presenting up to 2 months after a long-haul flight rises 17-fold from 0.03 to 0.5 cases per million when travel exceeds 5000 km.[245] The reason for the discrepancy by an order of magnitude between the two studies is unclear, but the absolute risk appears low.

Determining which aspects of air travel may contribute to the increased risk of VTE has proved challenging. Hypobaric hypoxia itself does not seem to activate the coagulation system nor cause endothelial activation in healthy individuals.[246] A crossover study in healthy volunteers comparing an 8 h flight with a movie marathon and regular activity did show increased thrombin generation after the flight in some individuals, especially those with factor V Leiden mutation and/or taking oral contraceptives.[247] This suggests that some flight-specific factors such as hypobaric hypoxia and/or type of seating may be important in susceptible individuals.

Identifying individuals at higher risk is likely to be the first stage in a strategy to prevent VTE after prolonged air travel. The MEGA study was a case-control study of 1906 patients presenting with a first VTE and 1906 controls.[248] It showed that the risk of VTE was increased twofold by travel (flight and non-flight) for >4 h. Height >1.90 m increased the risk when travelling on land by a factor of 4.7, factor V Leiden mutation by 8.1 and those using oral contraceptives by >20. These risks were greater with air travel. BMI >30 kg/m^2 was associated with increased risk when travelling by land but not by air. Height <1.60 m was associated with increased risk during air travel but not by land. The only thrombophilia testing undertaken was analysis for factor V Leiden and prothrombin G20210A mutations, so no comment can be made about other acquired or heritable thrombophilic tendencies.

Another study which did not exclude patients with previous VTE found that the greatest risk factor in patients with presumed flight-related VTE was previous VTE (OR 63). The numbers in this study were small (46 patients and 92 controls).[249] Other risk factors included recent trauma, obesity, varicose veins, cardiac disease and immobility during the flight.

A recent study by Lehmann *et al*[245] found that 40% of patients with travel-related VTE had evidence of thrombophilia compared with 48% in the group with no other cause identified, although testing was not performed systematically. This suggests that thrombophilia is no more a risk factor for air travel-associated VTE than for non-provoked VTE.

The WRIGHT Project has yet to produce data on prevention of VTE during flight. Several studies (under the acronym LONFLIT) were published by a single research group from Italy,[250] but their data using low molecular weight heparin have not been replicated. There are no data on the use of aspirin for preventing air travel-associated VTE. It has been shown to reduce the rate of pulmonary embolism and deep venous thrombosis in postoperative patients (PEP trial),[251] but has been superseded by low molecular weight heparin due to its efficacy and side effect profile. Pneumatic compression devices appear to be no more effective than leg exercises so may only be relevant in patients who are sedated or immobile.[252]

One trial has assessed the effect of below-knee graduated elastic compression stockings in passengers flying >8 h.[239] None of the 100 passengers in the group assigned to stockings developed asymptomatic VTE compared with 12 of the 100 control passengers. Four patients developed superficial vein thrombosis

in the group assigned to stockings compared with none in the control group.

FURTHER RESEARCH

There is a need for further research to address the following:

- Which physiological variables can be used to predict arterial hypoxaemia with particular attention to outcome of air travel as measured by level of symptoms, functional ability and post-flight respiratory status? The role of the 6MWT, TLCO and symptom scores such as the MRC dyspnoea scale merits particular investigation.
- What is the effect of exercise on altitude-induced hypoxaemia?
- Does commercial air travel increase the risk of developing subsequent lower respiratory tract infection in the 6 weeks after travel and does this correlate with length of flight?
- Does the level of in-flight hypoxaemia predict the frequency of adverse respiratory events in the 6 weeks after air travel?
- What is the impact of flight duration on the risk of respiratory complications?
- What is the stability of opioids when delivered by external or internal battery-driven pumps for pain relief in advanced cancer in low pressure environments?
- What proportion of patients use their CPAP machines in-flight and do they encounter any difficulties in using them?
- Do patients with OSAS sleep in-flight or do they try to avoid sleeping?
- Do patients on CPAP who sleep in-flight without using CPAP experience sequelae such as worsened jet lag or increased difficulty driving after flying?
- How do in-flight sleep studies performed in patients with OSAS who do not use their CPAP on board compare with ground level sleep studies?
- Do patients flying for bariatric surgery encounter respiratory complications after air travel?
- Do patients with obesity hypoventilation syndrome suffer adverse effects during or after air travel?
- How do in-flight sleep studies conducted on patients with obesity hypoventilation syndrome compare with ground level sleep studies?
- What is the frequency and nature of flight-related adverse respiratory events in patients with PAVM?
- Are hypoxaemic patients with PAVM more prone to respiratory complications after air travel and, if so, is a threshold for risk demonstrable?
- Does the provision of in-flight oxygen reduce the risk of adverse respiratory events in patients with PAVM?
- What are patients' and healthcare practitioners' views on how easy it is to access and administer low molecular weight heparin to at-risk individuals?
- How acceptable to patients is use of in-flight oxygen?
- Do passengers requiring supplementary oxygen in-flight respond similarly to pulsed dose and continuous flow systems?
- Do fitted and over-the-counter stockings differ in their effects on blood flow patterns in the lower limbs?
- Does aspirin reduce the incidence of asymptomatic deep vein thrombosis in low-risk individuals?
- What is the incidence of in-flight acute hyperventilation/panic attacks in different groups of passengers?
- What features enable flight crews to distinguish between hyperventilation and an acute medical crisis on board?
- Are short-acting anxiolytics safe and efficacious when used in-flight for hyperventilation or panic attacks?
- What are the risk and benefits of using psychotropic medication in passengers suffering from repeated anxiety attacks while flying?

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APPENDIX 2
Reviewers

Airline Medical Directors Association
Association of Respiratory Nursing Specialists
Association for Respiratory Technology & Physiology
Aviation Health, MedAire UK
Aviation Medical Services, Qantas Airways
British Airways
British Geriatrics Society
British Paediatric Respiratory Society
British Paramedic Association
British Sleep Society
Civil Aviation Authority
College of Emergency Medicine
Intensive Care Society
Joint Royal Colleges Ambulance Liaison Committee
Primary Care Respiratory Society (PCRS-UK)
Royal College of Physicians, Edinburgh
Royal College of Physicians, London
Royal College of Physicians and Surgeons, Glasgow
Royal College of Surgeons of Edinburgh
Royal College of Surgeons of England

APPENDIX 3
Revised SIGN grading system for recommendations and levels of evidence

Revised SIGN grading systems for grades of recommendation and levels of evidence are based on Annex B of SIGN B available at http://www.sign.ac.uk/

	Levels of evidence
1++	High quality meta-analyses, systematic reviews of randomised controlled trials (RCTs) or RCTs with a very low risk of bias
1+	Well-conducted meta-analyses, systematic reviews or RCTs with a low risk of bias
1−	Meta-analyses, systematic review or RCTs with a high risk of bias
2++	High quality systematic reviews of case-control or cohort studies, or high quality case-control studies with a very low risk of confounding bias and a high probability that the relationship is causal
2+	Well-conducted case-control or cohort studies with a low risk of confounding or bias and a moderate probability that the relationship is causal
2−	Case-control or cohort studies with a high risk of confounding or bias and a significant risk that the relationship is not causal
3	Non-analytical studies (eg, case reports, case series)
4	Expert opinion
	Grades of recommendations
A	At least one meta-analysis, systematic review or RCT rated as 1++ and directly applicable to the target population; or a body of evidence consisting principally of studies rated as 1+, directly applicable to the target population and demonstrating overall consistency of results
B	A body of evidence including studies rated as 2++, directly applicable to the target population and demonstrating overall consistency of results; or extrapolated evidence from studies rated as 1++ or 1+
C	A body of evidence including studies rated as 2+, directly applicable to the target population and demonstrating overall consistency of results; or extrapolated evidence from studies rated as 2++
D	Evidence level 3 or 4; or extrapolated evidence from studies rated as 2+
✓	Recommended best practice based on the clinical experience of the Air Travel Working Party

APPENDIX 4
National referral centres with decompression chambers

1. RAF Centre for Aviation Medicine, RAF Henlow, Hitchin, Bedfordshire SG16 6DN. Tel 01462 851 515.
2. QinetiQ Centre for Human Sciences, A50 Building, Cody Technical Park, Farnborough, Hampshire GU14 OLX. Tel 01252 392 600 (Facility Manager) or 01252 393 231.

APPENDIX 5
Major destinations exceeding 8000 ft (2438 m)

This is not an exhaustive list and passengers are recommended to contact the carrier if they suspect their destination may be at high altitude.

Airport	**Altitude (feet)**
Bangda, Tibet	15 548
Bengdag, China	14 100
Bogota, Colombia	8 355
La Paz, Bolivia	13 310
Lhasa, Tibet	14 315
Quito, Ecuador	9 222
Telluride, USA	9 086

APPENDIX 7

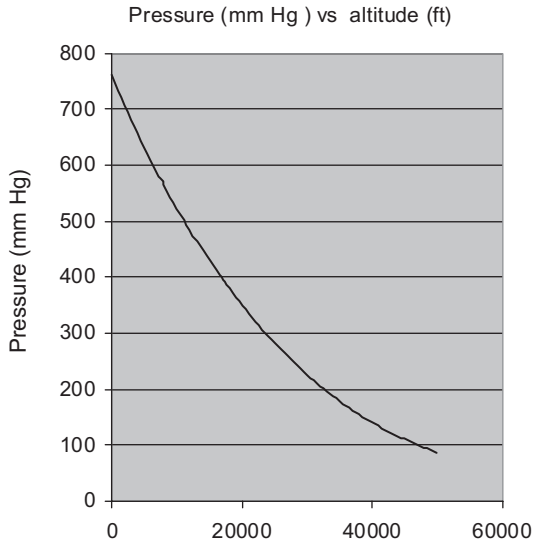

Figure AI Relationship between atmospheric pressure (mm Hg) and altitude (ft).

Boyle' s law illustrated for gas saturated with water vapour

Boyle's law predicts that as pressure falls the volume of a gas will increase proportionately (at a constant temperature). This inverse relationship is of great significance for all who fly, and the effects of the pressure reduction on gas volumes is slightly more marked than that predicted by Boyle's law for body cavities containing gas saturated with water vapour. Relative expansion of humidified gas is expressed as follows:

$$\frac{\text{(Initial pressure of the gas in the cavity at sea-level (mm Hg) – 47 mm Hg)}}{\text{(final pressure of gas in the cavity (mm Hg) – 47 mm Hg)}}$$

where 47 mm Hg is water vapour pressure at 37^{0}C. Assuming sea level atmospheric pressure of 760 mm Hg and atmospheric pressure of 565 mm Hg at 8000 ft, this equation becomes:

(760–47) / (565–47) = 713/518 = 1.38

This means a 38% expansion for a humidified gas, compared with 34% for a dry gas.

Figure AII Boyle's law illustrated for gas saturated with water vapour.

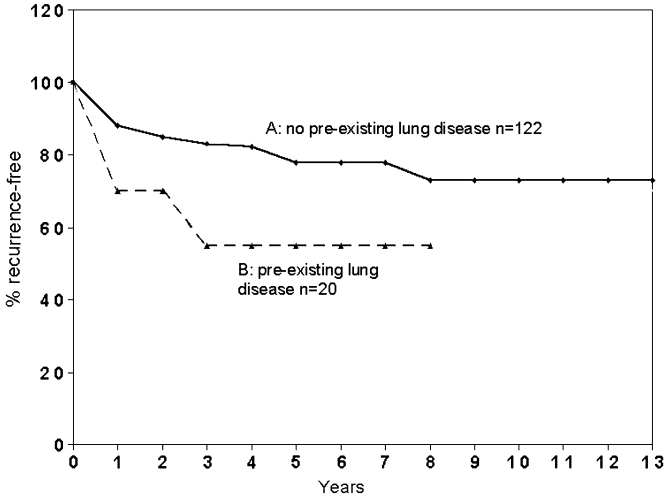

Figure AIII Cumulative freedom from pneumothorax recurrence in relation to pre-existing lung disease (adapted with permission from Lippert *et al*[219]).

SaO_2 %	PaO_2 kPa	PaO_2 mm Hg
97	12.7–14.0	95–105
94	9.3–10.0	70–75
92	8.9–9.7	67–73
90	7.7–8.3	58–62
87	6.9–7.7	52–58
84	6.1–6.9	46–52

Figure AIV Conversion algorithm: saturations to kPa to mm Hg.

Feet	Metres	Feet	Metres
1000	305	26000	7925
2000	610	27000	8230
3000	914	28000	8534
4000	1219	29000	8839
5000	1525	30000	9144
6000	1829	31000	9449
7000	2134	32000	9754
8000	2438	33000	10058
9000	2743	34000	10363
10000	3048	35000	10668
11000	3353	36000	10973
12000	3658	37000	11278
13000	3962	38000	11582
14000	4267	39000	11887
15000	4572	40000	12192
16000	4879	41000	12497
17000	5182	42000	12802
18000	5486	43000	13107
19000	5791	44000	13411
20000	6096	45000	13716
21000	6401	46000	14021
22000	6706	47000	14326
23000	7010	48000	14630
24000	7315	49000	14935
25000	7620	50000	15240

Figure AV Conversion chart from feet to metres.

APPENDIX 8
Examples of equations for predicting hypoxaemia

1. This relates PaO_2 at altitude (Alt) to PaO_2 at sea level (Ground)[44]: **PaO_2 Alt (mm Hg) = 0.410 × PaO_2 Ground (mm Hg) + 17.652**
2. This relates PaO_2 Alt to PaO_2 Ground & includes FEV_1 in litres[44]: **PaO_2 Alt = 0.519 × PaO_2 Ground (mm Hg) + 11.855 × FEV_1 (litres)−1.760**
3. This relates PaO_2 Alt to PaO_2 Ground and includes FEV_1 as % predicted[44]: **PaO2 Alt = 0.453 × PaO2 Ground (mmHg) + 0.386 × (FEV1% pred) +2.44**
4. This relates PaO_2 Alt to PaO_2 Ground and includes flight or destination altitude[45]: **PaO_2 Alt = 22.8−(2.74 x altitude in thousands of feet) + 0.68 × PaO_2 Ground (mm Hg)**

a) Thousands of feet should be entered as feet divided by 1000. 8000 feet would thus be entered in the equation as 8.0 not as 8000.
b) Both papers use mm Hg. One kPa = 7.5 mm Hg.

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