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BTS Clinical Statement on air travel for passengers with respiratory disease

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INTRODUCTION

BTS recommendations for managing passengers with stable respiratory disease planning air travel were published in *Thorax* in 2011.¹ This followed original guidance published in 2002² and an online update in 2004.³ The 2011 recommendations provided an expert consensus view based on literature reviews, aimed at providing practical advice for lung specialists in secondary care. Recognising that knowledge in this area has grown since 2011, and that updated, pragmatic advice regarding which respiratory patients need specialist assessment is required, the Society has commissioned a new clinical statement.

Although air travel appears generally safe for those with respiratory disease assessed previously by a lung specialist,⁴ a decision to undertake air travel should not be taken lightly. Diverted flights incur significant expense and inconvenience, and a patient whose condition deteriorates during flight can pose huge challenges to airline crew and other passengers. High altitude destinations may also be problematic.

European and North American regulatory authorities limit maximum cabin altitude to 2438 m (8000 ft) under normal operating conditions.^{5–7} The choice of 2438 m was based on the oxyhaemoglobin dissociation curve, which shows that up to this level arterial oxygen saturations (SaO₂) remain >90% in the average healthy individual.⁸ Some newer commercial aircraft have a lower normal cabin altitude, for example, the Boeing 787 Dreamliner. However, passengers booking such flights should note that airlines may, for operational reasons, switch at short notice to an aircraft with a higher normal cabin altitude.

Besides the passenger's respiratory condition and significant comorbidities, a decision regarding suitability for air travel should consider flight duration and timings, destination (especially if at altitude or subject to extreme weather conditions), equipment and medications, and whether equipment will operate effectively and safely at altitude.

There have been developments in three key areas over the last decade. The first is an attempt, with research from several groups, to define more precisely the value and role of the hypoxic challenge test (HCT). This has included examining the accuracy of other, more routinely available lung function parameters, in predicting hypoxaemia during air travel. HCT can be expensive in terms of equipment and consumables; and demands additional

staff time. A 'negative' HCT (where in-flight oxygen is not considered necessary) takes around 30 min; if oxygen titration is needed it takes around 60 min. In contrast, spirometry requires 20 min, a walk test 30 min, and 'full' lung function testing 45 min.⁹ Results of such assessments may already be available as part of routine clinical care.

The second development has been increasing recognition that, although early research in this area focused on patients with chronic obstructive pulmonary disease (COPD), other patient groups may respond differently to altitude-related hypoxaemia. Although data remain limited, available evidence no longer appears to support a 'one size fits all' approach.

Finally, the equipment used to deliver oxygen has changed significantly over the last decade, with much greater availability of portable oxygen concentrators (POCs). For overseas travel, patients usually need to lease a POC privately, since UK companies do not generally allow their equipment to be taken out of the country. If a POC is to be used in-flight, the equipment must be approved by the airline before travel. There are now a wide variety of such devices, providing varying flow rates and modes of delivery (continuous flow vs pulse-dose), and not all are suitable for all individual patients.

Attention has, therefore, been drawn in this Statement to newer data, especially those published since the 2011 BTS recommendations.¹ Readers wanting more detailed background information on physiology and the flight environment should consult the 2002 and 2011 BTS documents.^{1,2}

Scope

The clinical statement provides practical advice for healthcare professionals in primary and secondary care managing passengers with pre-existing respiratory conditions planning commercial air travel, including those recovering from an acute event/exacerbation. It provides information for patients and carers; and is also intended to be helpful to patient support groups, airlines and associated medical services. Passengers returning home with a new diagnosis should be reviewed in the light of the presenting condition and individual circumstances. The document does not cover emergency aeromedical evacuation, or travel on non-commercial flights. Pregnant passengers with respiratory disease should also consult Royal College of Obstetricians and Gynaecologists guidance (see online supplemental appendix 1).

The Statement addresses adults and children with the following conditions or undergoing the following procedures:

- ▶ Airflow obstruction including asthma and COPD.
- ▶ Bronchopulmonary dysplasia.
- ▶ Cystic fibrosis (CF).
- ▶ Non-CF bronchiectasis.
- ▶ Restrictive respiratory disease including interstitial lung disease (ILD), respiratory muscle and chest wall disorders.
- ▶ Thoracic surgery or other interventional procedures.
- ▶ Pleural disease including pneumothorax and pleural effusion.
- ▶ Respiratory infections.
- ▶ Obstructive sleep apnoea syndrome (OSAS) and obesity hypoventilation syndrome (OHS).
- ▶ Venous thromboembolism (VTE).
- ▶ Pulmonary hypertension (PH).
- ▶ Lung cancer and mesothelioma.
- ▶ Hyperventilation and dysfunctional breathing (DB).

Preflight assessment is described. Appendix A provides information on logistics for air travel with equipment (nebulisers, oxygen and ventilators); Appendix B provides technical information for respiratory physiologists. Sources of useful information, Information for primary care healthcare practitioners and for patients are provided in online supplemental appendices 1–3.

Heart disease and HIV are excluded, as are emergency repatriation and travel on military or other non-commercial flights including helicopter travel. The Terrence Higgins Trust and British Heart Foundation provide advice on travel with HIV and heart conditions respectively (see online supplemental appendix 1).

METHODOLOGY

Dr Robina Coker chaired the clinical statement group (CSG). Membership was drawn from respiratory medicine, paediatrics, nursing, respiratory physiology, physiotherapy and primary care. The CSG identified key areas requiring Clinical Practice Points. The group reviewed previous BTS recommendations on this topic^{1–3} and supplemented the evidence with up-to-date literature searches. The overall content was developed to reflect the scope approved by the BTS Standards of Care Committee (SOCC). Following discussions of broad statement content, individual sections were drafted by group members. A final edited draft was reviewed by the BTS SOCC before posting for public consultation and peer review on the BTS website in January 2020. The document was revised in the light of consultation feedback and approved by the BTS Standards of Care Committee in July 2021 before final publication.

Summary of clinical practice points

Preflight screening

- ▶ All patients should undergo careful initial evaluation with history and physical examination by a clinician who is competent. The history should include:
 - Review of symptoms, baseline exercise capacity, recent exacerbation history, treatments and previous experience of air travel.
 - Consideration of the logistics of the intended journey, to include (if known):
 - Number and duration of flights, including whether daytime or overnight,
 - Location of stop-over(s) and destination: these determine air quality, altitude and available medical facilities,
 - Time away from home

- Return journey.

- ▶ Further assessment by a respiratory specialist is advised for those in whom screening raises concerns, and HCT may be advised.

The following clinical practice points are specific to infants and children

- ▶ For infants born at term (>37 weeks) it is prudent to delay flying for 1 week after birth to ensure they are healthy.
- ▶ Infants born prematurely (<37 weeks) with or without a history of respiratory disease who have not reached their expected date of delivery at the time of flying should have in-flight oxygen available. HCT may not be a reliable guide of oxygen requirement in this group. If air travel is essential, they should travel with oxygen at a tolerable low flow, recognising that this may be a minimum of 1 L/min depending on equipment.
- ▶ Infants under 1 year with a history of chronic respiratory problems should be discussed with a respiratory paediatrician and HCT considered. Those with SpO₂ <85% on HCT should have in-flight oxygen available; paediatrician discretion should be used for infants with SpO₂ 85%–90% recognising that sleep or respiratory infection may further reduce saturations in this group.
- ▶ In children with chronic lung disease able to perform spirometry whose forced expiratory volume in 1 s (FEV₁) is consistently <50% predicted, HCT should be considered. This includes children with CF and primary ciliary dyskinesia (PCD). Children with chronic lung disease who are too young to perform spirometry reliably should have a clinical assessment of disease severity and their likely tolerance of hypoxia. In children with CF the disease is rarely severe enough to compromise lung function significantly at this age.
- ▶ Infants and children who have required long-term oxygen in the last 6 months should be discussed with a respiratory paediatrician and HCT considered.

Patient selection for HCT

See [figures 1 and 2](#).

The following patients should not require HCT

- ▶ Those with stable disease who have previously undergone HCT (no recent hospital admissions, exacerbations, or significant changes to treatment).
- ▶ Patients with COPD with baseline SpO₂ ≥95% and either MRC score 1–2 or desaturation to no less than 84% during 6 min walk test (6MWT) or shuttle walking test (SWT), should be able to travel without in-flight oxygen.
- ▶ Those with previous significant intolerance to air travel, such as mid-air emergency oxygen or diversion. These should have in-flight oxygen available at 2 L/min provided there is no history of hypercapnia.
- ▶ Preterm infants who have not reached their due date at the time of travel, as testing is not a reliable guide of oxygen requirement in these infants. These should have in-flight oxygen available, delivered at 1–2 L/min if they develop tachypnoea, recession, or other signs of respiratory distress.

HCT should be considered for the following patients

- ▶ Patients with COPD with resting SpO₂ ≤95%, MRC score 3 or greater, or desaturation to <84% on 6MWT or SWT, and in whom there are concerns about hypercapnia.

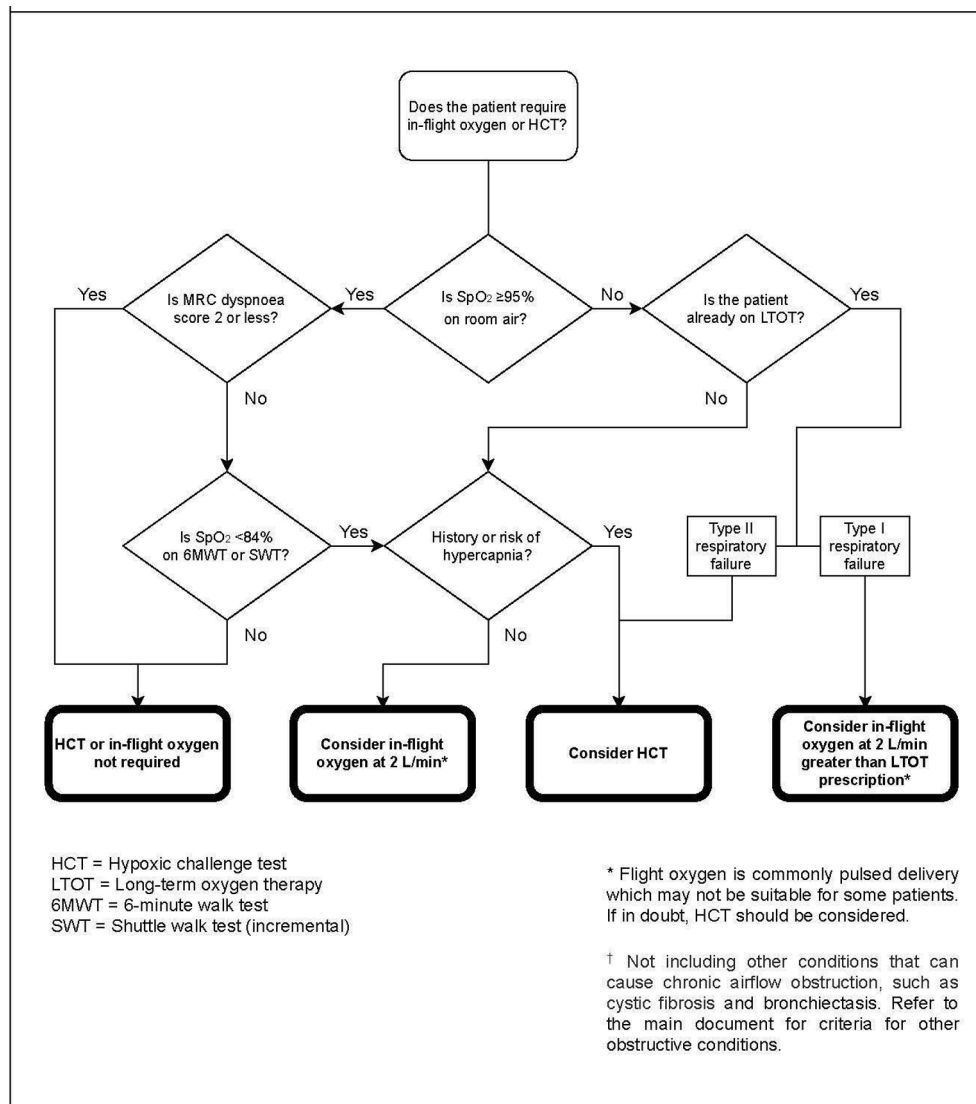


Figure 1 Preflight assessment of patients with chronic airflow obstruction.

- ▶ Infants and children with a history of neonatal respiratory problems, or existing severe chronic lung disease including those with FEV1 persistently <50% predicted.
- ▶ Adults and children with severe asthma, evidenced by persistent symptoms and/or frequent exacerbations despite optimal treatment regardless of resting sea level SpO₂.
- ▶ Patients with ILD in whom SpO₂ falls to <95% on exercise, and whose resting sea level arterial oxygen tension (PaO₂) is ≤9.42 kPa or whose TLCO is ≤50%.
- ▶ Those with severe respiratory muscle weakness or chest wall deformity in whom forced vital capacity (FVC) is <1L.
- ▶ Those with existing or previous hypercapnia and those at risk of hypercapnia, including those taking medication(s) which can cause respiratory depression.
- ▶ Patients with a history of type 2 respiratory failure already on LTOT at sea level. However, if there is no evidence of hypercapnia, it seems reasonable to recommend an increase in flow rate by 2L/min in-flight, provided the equipment can provide it (see Appendix A)
- ▶ PaO₂ <6.6 kPa (<50 mm Hg) or SpO₂ <85%: in-flight oxygen recommended.
- ▶ Where required, titrate oxygen to maintain PaO₂ ≥6.6 kPa or SpO₂ ≥85% in adults, SpO₂ 90% in children aged 1 year or more.

Asthma

- ▶ The patient's condition should be optimised before travel, with attention paid to inhaler technique and smoking cessation referral as required.
- ▶ All medications and spacer devices should be carried in hand luggage to mitigate the risk of lost or missing hold baggage.
- ▶ Emergency medications, including salbutamol inhalers and spacers, must be immediately accessible.
- ▶ Individuals prescribed epinephrine auto-injectors should have them readily available.
- ▶ For acute exacerbations on board, the passenger's own bronchodilator inhaler should be given, with a spacer if needed.
- ▶ The passenger should alert the cabin crew if symptoms do not respond rapidly to use of the inhaler, or if they recur after a short interval.

HCT results

- ▶ PaO₂ ≥6.6 kPa (≥50 mm Hg) or SpO₂ ≥85%: in-flight oxygen not required.

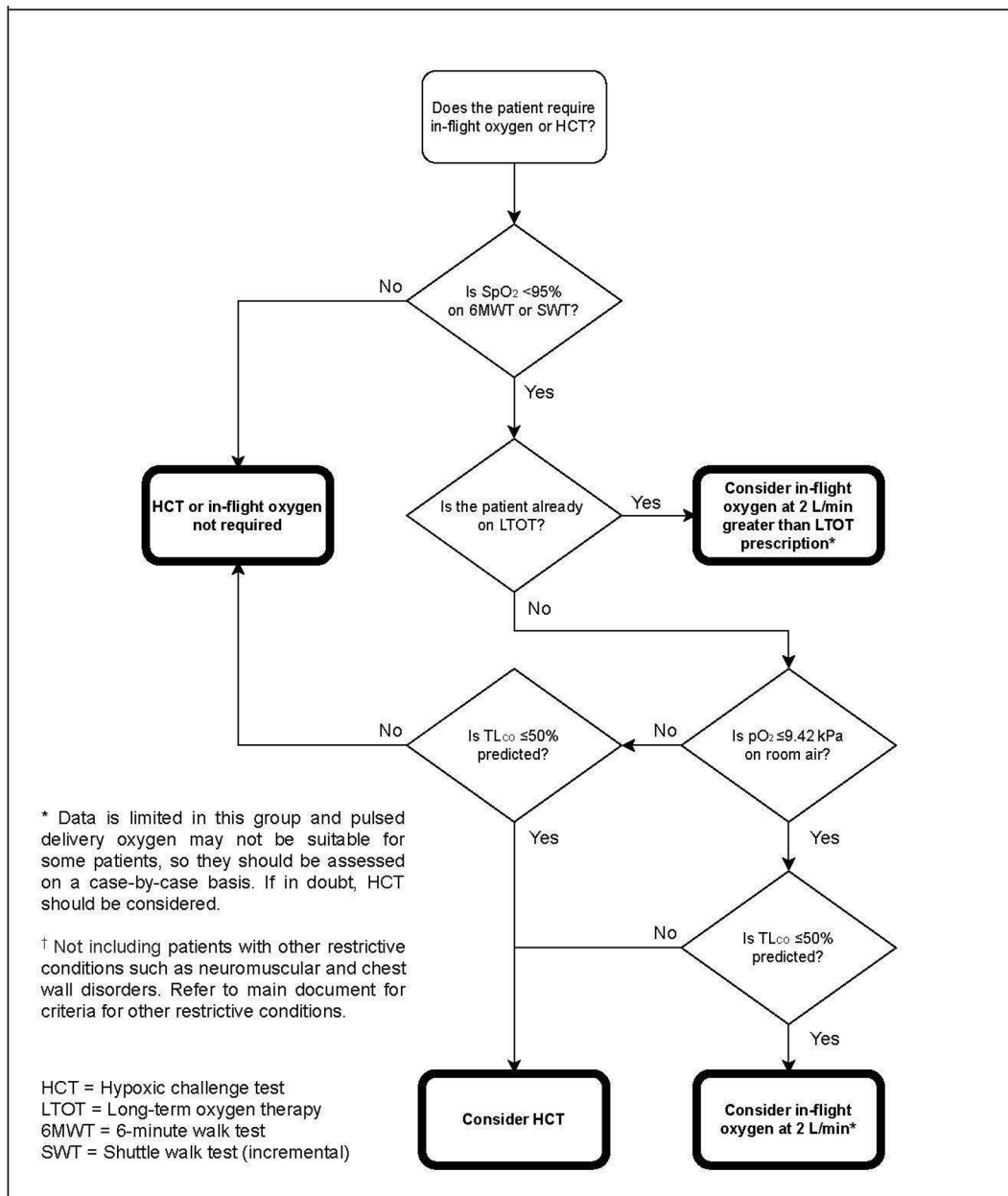


Figure 2 Preflight assessment of patients with restrictive respiratory disease.

- ▶ If the passenger does not have their own inhaler with them, or if it is inaccessible, the airline may carry an inhaler in the emergency medical kit. Spacers are not commonly available.
- ▶ Those with severe asthma should consult their respiratory specialist beforehand and consider taking an emergency supply of oral corticosteroid in their hand luggage in addition to their usual medication.
- ▶ Passengers with severe asthma are advised to carry copies of their asthma management plan and/or relevant clinic letters. Information can be held securely as scanned copies on a mobile phone, or on a digital platform such as the National Health Service (NHS) App.
- ▶ Food allergy affects up to 8.5% of children and adults with asthma and asthma is a risk factor for severe or fatal anaphylaxis. Appropriate precautions for those affected include wiping tray tables and hands, informing the airline beforehand and the cabin crew of allergies, and not eating during flights or bringing known ‘safe’ foods from home.

Chronic obstructive pulmonary disease

- ▶ The patient’s condition should be optimised before travel, with attention paid to inhaler technique and smoking cessation referral where appropriate.
- ▶ All medications and spacer devices should be carried in hand luggage to mitigate the risk of missing hold baggage.
- ▶ Emergency medications, including salbutamol inhalers and spacers, must be immediately accessible.
- ▶ For acute exacerbations on board, the passenger’s own bronchodilator inhaler should be given, with a spacer if appropriate.
- ▶ Passengers with severe COPD are advised to carry a copy of their COPD management plan and/or relevant clinic letters. This information can be held securely as scanned copies on their mobile phone. A history of previous pneumothorax or bullous lung disease necessitates assessment by a respiratory specialist to determine the potential risk of complications from reduced cabin pressure.

- ▶ Patients with COPD are at greater risk of VTE as a direct consequence of the underlying condition, as well as after an exacerbation. They should be advised accordingly, especially if planning longer flights when the risk is further enhanced.
- ▶ Patients requiring long-term oxygen therapy should also plan for oxygen supplementation at their destination (see online supplemental appendix 1).
- ▶ Wherever possible, those who have had a recent exacerbation of their condition should not fly until their condition is stable and use of reliever therapy has returned to their usual baseline. If their condition deteriorates while overseas, medical advice should be sought before undertaking the return flight.

Cystic fibrosis

- ▶ All medications and spacer devices should be carried in hand luggage to mitigate the risk of missing hold baggage.
- ▶ Patients with CF under the age of 6 are likely to be well enough to fly at the paediatrician's discretion.
- ▶ In those with CF who are old enough for spirometry and whose FEV₁ is <50% predicted, HCT is recommended. If SpO₂ falls below the 90% cut-off, as outlined above, in-flight oxygen is advised.
- ▶ In children with chronic lung disease able to perform spirometry whose FEV₁ is consistently <50% predicted, HCT should be considered. This includes children with CF and non-CF bronchiectasis. Children with chronic lung disease who are too young to reliably perform spirometry should have a clinical assessment of disease severity and their likely tolerance of hypoxia. For children with CF disease is rarely severe enough to severely compromise lung function at this age.

Non-CF bronchiectasis

- ▶ Regular airway clearance is essential for those dealing with overproduction of mucus.
- ▶ Advice from a respiratory physiotherapist on adapting airway clearance techniques should be sought for long-haul flights.
- ▶ Portable nebulisers and positive expiratory pressure (PEP) devices may be considered, but use of these devices in-flight must be approved by the airline before travel.

Interstitial lung disease

- ▶ In patients with comorbidity, including PH and/ or cardiovascular disease, attention should also be paid to the impact of air travel on these conditions.
- ▶ Physicians may wish to consider HCT in those whom SpO₂ falls to <95% on exercise, and/or in those in whom either Transfer Factor Carbon Monoxide (TLCO) ≤50% or PaO₂ ≤9.42 kPa (if available).
- ▶ Patients with TLCO <50% of predicted or PaO₂ ≤9.42 kPa are likely to need in-flight oxygen. If there are no concerns about hypercapnia it may be reasonable to recommend 2L/min without recourse to HCT. In those in whom there are concerns about CO₂ retention, titration HCT is advised to determine the oxygen flow rate.

Thoracic surgery

- ▶ The opinion of the surgeon or interventionalist should be obtained before the patient travels by air. Patients, professionals and their carers should be aware that this may result in a delay of 4 weeks for non-essential air travel and 2 weeks for essential air travel.

- ▶ Careful clinical assessment of the patient is required. This should include consideration of their baseline status including comorbidities, SpO₂, postprocedure complications such as infection and/or pain, flight duration and destination.

Other interventional procedures

- ▶ The opinion of the interventionalist should be obtained before the patient travels by air.
- ▶ Careful clinical assessment of the patient is required. This should include consideration of baseline status including co-morbidities, SpO₂, postprocedure complications such as infection or pain, flight duration and destination.
- ▶ Patients with no pneumothorax seen on the postprocedure chest X-ray should wait for 1 week before air travel.
- ▶ Patients with a pneumothorax seen on the post-procedure chest X-ray should wait for one week after resolution on chest X-ray before air travel.

Trapped lung

- ▶ The opinion of the interventionalist should be obtained before the patient travels by air.
- ▶ Patients should be assessed carefully and advised on a case-by-case basis.
- ▶ Patients should be clinically stable before air travel.

Bronchoscopic procedures

- ▶ The opinion of the interventionalist should be obtained before the patient travels by air.
- ▶ Patients should be clinically stable before they travel.
- ▶ After interventional bronchoscopy including Transbronchial Needle Aspiration (TBNA), Transbronchial Lung Biopsy (TBB), Endobronchial Ultrasound Bronchoscopy (EBUS) and endobronchial valve insertion, those with no pneumothorax seen on the postprocedure chest X-ray should wait for 1 week before air travel.
- ▶ After interventional bronchoscopy including TBNA, TBB and EBUS, those with a pneumothorax seen on the post-procedure chest X-ray should wait for 1 week after resolution on chest X-ray before air travel.

Pneumothorax

- ▶ Passengers should not travel by air until 7 days after full resolution on chest X-ray.
- ▶ Those at higher risk of recurrent pneumothorax should be advised accordingly.
- ▶ Higher-risk groups, including those with cystic lung disease such as lymphangiomyomatosis (LAM) and Birt-Hogg-Dubé (BHD) syndrome, should be advised accordingly.
- ▶ Patients with trapped lung and a chronic air space thought to present a low risk should be evaluated in secondary care before travel.

Upper respiratory infection including otitis media and sinusitis

- ▶ In passengers who develop sinus barotrauma after flying, it may be helpful to consider topical and oral decongestants as well as appropriate analgesia. Prolonged use of decongestants is not advised owing to the risk of rebound congestion on withdrawal.
- ▶ If there is an allergic component, intranasal steroids used for a week prior to travel, and/or oral corticosteroids may be considered.
- ▶ Symptoms and signs of barotrauma should have resolved before flying again. This usually takes between 1 and 6 weeks.

Table 1 Summary of risk factors for VTE during air travel

Risk status	Risk factors	Advice
All passengers	Low	Avoid excess alcohol and caffeine-containing drinks Remain mobile/exercise legs
Moderate risk	Examples include: Aged over 60 Extensive varicose veins Recent minor surgery Pregnancy	Above plus consider: Take short periods of sleep Support hosiery/graduated compression stockings
High risk	Examples include: Previous VTE (and not on current anticoagulation) Thrombophilia Within 6 weeks of major surgery Current malignancy	If travel is essential, consider: low-molecular-weight heparin or formal anticoagulation (including return journey) This requires careful clinical assessment

VTE, venous thromboembolism.

- ▶ After an episode of acute otitis media, patients are usually advised not to fly for 2 weeks.

Viral infections

- ▶ Patients with highly contagious infections including measles, chickenpox, mumps, SARS, Middle East respiratory syndrome (MERS) or COVID-19 should not be allowed to travel until they are considered non-infectious.
- ▶ Passengers should familiarise themselves with current national and international regulations regarding air travel, which should always be observed.

Tuberculosis

- ▶ Smear positive patients must not fly until they have provided two smear negative samples on treatment.
- ▶ Those starting treatment for pulmonary tuberculosis (TB), where not all the information is yet available, should not travel by air for the first 2 weeks.
- ▶ For those who are smear negative and have a fully sensitive organism, treatment would be expected to render them non-infectious after 2 weeks.
- ▶ For patients with multidrug resistant/extensive drug resistant (MDR/XDR) TB, travel is prohibited until two negative culture samples have been produced and there is clinical evidence of improvement on treatment.
- ▶ Extrapulmonary TB does not usually warrant additional precautions before air travel.

Pneumonia

- ▶ All but essential travel should be postponed for 7 days in those who have reduced baseline sea level SpO₂ (<94%).

Obstructive Sleep Apnoea (OSAS) and Obesity Hypoventilation Syndrome (OHS)

- ▶ Daytime flights are advised wherever possible.
- ▶ The patient should be advised to carry their continuous positive airway pressure (CPAP) device as hand luggage, and a hospital letter to advise that the patient uses CPAP.
- ▶ Careful planning and preparation are required, and use of the patient's own CPAP device is advised.
- ▶ Alcohol and sedatives should be avoided in the 12 hours before, and during, airline travel.
- ▶ Patients should use their CPAP device on board if they are travelling overnight, and avoid sleeping during daytime flights.

- ▶ Consideration should be given to device settings and whether adjustment is required for operation at altitude.
- ▶ Airline approval for carriage and use of device, including battery specification, must be gained before travel.
- ▶ Consideration should be given to the whole journey. If driving is required the following day, an overnight stay at destination may be advisable. Patients are advised to refrain from driving if tired and sleepy.

Respiratory muscle and chest wall disorders

- ▶ HCT is recommended for all adult patients with FVC <1 L, pending further data, and may be considered in others thought to be at particular risk, including children with reduced FVC due to respiratory muscle or chest wall disorders.
- ▶ If patients are unable to perform spirometry reliably, a walk test may be considered as an alternative.
- ▶ Patients should be advised to take daytime flights where possible.
- ▶ Further planning and support are required for those established on non-invasive ventilation (NIV) (see Appendix A). (online supplemental appendix 2)

Prevention of VTE during air travel

See [table 1](#).

- ▶ Limit the risk of dehydration with adequate fluid intake.
- ▶ Avoid alcohol.
- ▶ Keep mobile, if possible, by walking around or doing seat-based exercises once an hour.
- ▶ Consider graduated compression stockings (class 1 with 15–30 mm Hg).
- ▶ Low molecular weight heparin (LMWH) or a Direct Acting Oral Anticoagulant (DOAC) are advised for both outward and return long haul flights (long haul defined as flights of 6–12 hours) in high-risk patients including those with a history of VTE; local policy should be followed regarding liaison with primary care and/or haematology services to teach the patient how to administer the injection and dispose safely of the equipment. There is no formally recommended dose, but enoxaparin at a dose of 40 mg or weight based 1 mg/kg injected once 4–5 hours before the flight has been suggested.
- ▶ The prophylactic doses of the DOAC may also be used.
- ▶ All patients with a recent (<6 weeks) history of VTE, especially any who presented with significant right ventricular strain and decompensation should be reassessed before air travel.

Air travel after VTE

- ▶ Air travel should be delayed for 2 weeks after a diagnosis of DVT or pulmonary embolism (PE).

Pulmonary hypertension

- ▶ Those in New York Heart Association (NYHA) WHO functional class 3 or 4 are usually advised to have in-flight oxygen. If there is no evidence of hypercapnia it seems reasonable to suggest 2 L/min by nasal cannulae. If there are concerns about hypercapnia, HCT should be considered if available.
- ▶ Those eligible for LTOT (sea level PaO₂ <8 kPa at rest on air) should have in flight oxygen at double the flow rate recommended at sea level, provided there is no evidence of hypercapnia.

Lung cancer and mesothelioma

- ▶ Patients undergoing chemotherapy should not travel while they are at increased risk of infection or suffering from significant side effects, such as vomiting.

Hyperventilation and DB

- ▶ Patients with DB, inducible laryngeal obstruction (ILO) and/or vocal cord dysfunction (VCD) should be referred to a respiratory physiotherapy specialist for advice on symptom management before travel.
- ▶ Those with anxiety disorders should be reviewed before travel; compliance with medication assessed; and use of short acting anxiolytics encouraged.
- ▶ Other life-threatening conditions presenting with dyspnoea should be excluded on board as far as possible.
- ▶ Supplemental oxygen should be given on board if the cause of breathlessness is unclear
- ▶ Rebreathing via a paper bag is not recommended.

HCT outcomes

Preflight respiratory screening

Why?

Medical incidents have been reported in around 1 in 600 flights,¹⁰ or 1 in 30 000 passengers.^{11 12} Estimates vary and reliable data are difficult to obtain, but respiratory events account for around 12% of in-flight incidents. In a recent study of 1260 healthy volunteers, no significant changes occurred in pulse oximetry (SpO₂) during a simulated 8-hour flight at cabin altitudes up to 2438 m (8000 ft).¹³ However, if cabin altitude exceeds 3048 m (10 000 ft), hypoxaemia becomes more prominent and SaO₂ falls to ~89% in healthy individuals.¹⁴ Other potential hazards for passengers with respiratory conditions include low relative humidity, and altitude-related expansion of gases within enclosed pulmonary parenchymal spaces. It follows from Boyle's Law that a cabin altitude of 2438 m (8000 ft) will result in a 38% expansion of humidified gas.

Who?

There is no good-quality evidence to determine who should have a formal respiratory review before air travel. Experts generally advise preassessment or screening for the following adults, children and infants:

- ▶ Those with a respiratory condition with the potential to deteriorate acutely resulting in incapacitation and/or the need for medical intervention. This includes (but is not exclusive to):
 - Severe (FEV1 <50% predicted¹⁵ or poorly controlled obstructive airway disease (evidenced by symptoms, oxygen requirements, severe and/or frequent exacerbations).
 - Symptomatic restrictive lung or chest wall conditions, or known respiratory muscle weakness causing breathlessness and exercise limitation.
 - PH.
 - Comorbid conditions which may be worsened by hypoxaemia (cerebrovascular or cardiac disease).
 - Recent (<6 weeks) hospital treatment for a respiratory condition.
 - Requirement for CPAP or ventilator support such as NIV.
 - Active cancer with lung involvement.
 - Patients requiring domiciliary oxygen.
- ▶ Recent (<6 weeks) pneumothorax and those at higher risk of pneumothorax (cystic lung disease or recurrent pneumothorax), and patients with trapped lung and a chronic air space.

- ▶ Recent (<6 weeks) pulmonary embolus or deep venous thrombosis, or increased risk of VTE.
- ▶ Anyone who has experienced significant symptoms during previous air travel, or whose condition is of concern to their physician.

The following are generally considered contraindications to air travel:

- ▶ Untreated respiratory failure.
- ▶ Untreated pneumothorax.
- ▶ Active infection representing a risk to others for example, TB, SARS, MERS, COVID-19.
- ▶ Bronchogenic cysts. Cerebral air embolism, in some cases fatal, has been reported in aircraft passengers after rupture of a bronchogenic cyst.¹⁶
- ▶ Patients with severe hypoxaemia requiring >4L/min in-flight oxygen were previously advised against air travel, because 4L/min was the maximum fixed flow rate routinely available on commercial aircraft. With the availability of flight approved POCs delivering a range of continuous and intermittent flow rates, this cut-off no longer applies. In-flight oxygen delivery is more varied, and maximum flow rate is determined by the equipment available. Pulse-dose delivery systems can however complicate determination of the flow delivered and may not be well tolerated. The effects of mouth-breathing, speech, snoring and/or sleeping should be considered. High-flow nasal oxygen (HFNO) cannot be delivered on board commercial aircraft.

In-flight oxygen may be contraindicated in adults and children with a history of type 2 respiratory failure.^{17 18} Hypoxic challenge with arterial carbon dioxide tension (PaCO₂) measurement was advised for this group in 1996¹⁷ but there has been little research since. This document, therefore, follows the 2015 BTS Guideline for Home Oxygen Use in Adults¹⁹ when making recommendations for managing patients with previously documented hypercapnia.

Clinical practice points

- ▶ All patients should undergo careful initial evaluation with history and physical examination by a clinician who is competent. The history should include:
 - Review of symptoms, baseline exercise capacity, recent exacerbation history, treatments and previous experience of air travel.
 - Consideration of the logistics of the intended journey, to include (if known):
 - Number and duration of flights, including whether daytime or overnight.
 - Location of stop-over(s) and destination: these determine air quality, altitude and available medical facilities.
 - Time away from home.
 - Return journey.
- ▶ Further assessment by a Respiratory Specialist is advised for those in whom screening raises concerns, and hypoxic challenge testing may be advised.

Infants and children

In general, similar considerations apply to both adults and children if they have severe chronic airway disease, or require chronic supplementary oxygen, or non-invasive or tracheostomy ventilation. Both children and adults with these conditions require a preflight assessment. Similarly, unless otherwise stated, recommendations for individuals with previous thoracic surgery, pneumothorax or empyema apply to both adults and

children. There are, however, some specific considerations for infants and younger children since several factors place infants at greater risk of developing hypoxia. These factors include left shift of the oxygen dissociation curve (due to the presence of foetal haemoglobin), smaller airway diameter, relatively fewer alveoli, compliant rib cage and increased tendency to pulmonary vasoconstriction and bronchoconstriction and thus ventilation–perfusion mismatch under hypoxic conditions. Moreover, preterm infants and infants under 2 months of age may develop apnoea/hypoventilation in response to hypoxia or infection.^{20 21} Beyond 3 months of age there is no evidence that ex-preterm infants, without bronchopulmonary dysplasia, are at significantly greater risk of desaturation during a HCT than term infants.²²

In addition to very young and ex-preterm infants, the children most at risk of hypoxia are those with anaemia, congenital heart disease with an actual or potential right to left shunt,²³ neuromuscular disorders or chronic or acute lung disease. Low humidity during air travel can also present a problem for children with respiratory conditions such as CF. Those most at risk of complications associated with reduced air pressure are children with upper respiratory tract infections, or trapped intrathoracic air, including those with recent pneumothorax or cystic lung disease.²⁴

For infants born at term (>37 weeks) it is prudent to delay flying for 1 week after birth to ensure they are healthy.²⁵ In view of their greater risk of apnoea and hypoxia, infants born prematurely (<37 weeks) with or without a history of respiratory disease who have not reached their expected date of delivery at the time of flying should have in-flight oxygen available. HCT may not be a reliable guide of oxygen requirement in this group.²⁶ If air travel is essential, they should travel with oxygen at a tolerable low flow, recognising that this may be a minimum of 1 L/min depending on equipment.

The following Clinical Practice Points are specific to infants and children.

Clinical practice points

- ▶ For infants born at term (>37 weeks) it is prudent to delay flying for 1 week after birth to ensure they are healthy.
- ▶ Infants born prematurely (<37 weeks) with or without a history of respiratory disease who have not reached their expected date of delivery at the time of flying should have in-flight oxygen available. HCT may not be a reliable guide of oxygen requirement in this group. If air travel is essential, they should travel with oxygen at a tolerable low flow rate, recognising that this may be a minimum of 1 L/min depending on equipment.
- ▶ Infants under 1 year with a history of chronic respiratory problems should be discussed with a respiratory paediatrician and HCT considered. Those with SpO₂ <85% on HCT should have in-flight oxygen available; paediatrician discretion should be used for infants with SpO₂ 85%–90% recognising that sleep or respiratory infection may further reduce saturations in this group.
- ▶ In children with chronic lung disease able to perform spirometry whose FEV₁ is consistently <50% predicted, HCT should be considered. This includes children with CF and PCD. Children with chronic lung disease who are too young to perform spirometry reliably should have a clinical assessment of disease severity and their likely tolerance of hypoxia. In children with CF the disease is rarely severe enough to compromise lung function significantly at this age.

- ▶ Infants and children who have required long-term oxygen in the last 6 months should be discussed with a respiratory paediatrician and HCT considered.

How?

Pulse oximetry is the easiest and usually the first screening test.⁴ It has generally been accepted in the past that those with resting SpO₂ >95% at sea level should not require in-flight oxygen.^{2 25 27–30} Spirometry results may already be available in patients with known acute or chronic lung disease, or with symptoms suggesting lung disease.^{31 32} However, lung function parameters are in many cases poor at predicting hypoxaemia or complications.^{28 33–35}

Many airlines have historically considered that those able to walk 50 m or climb up 10–12 steps without distress have sufficient cardiopulmonary reserve to fly.^{2 36} The role of the 6MWT in preflight evaluation, widely used to assess functional capacity and exercise-induced hypoxaemia in COPD^{37–40} and ILD including IPF,^{41–43} has also been examined. Current data suggest that the 50 m walk test is an insensitive assessment of ‘fitness to fly’^{38 44 45} although still sometimes referenced.^{36 46 47} Several studies show no correlation between walking distance and HCT outcome in patients with COPD, ILD or extrapulmonary restriction.^{38 44 45 48} One study showed no correlation between exertional dyspnoea and HCT outcome.³⁸ The 50 m walk test alone thus appears unsuitable for preflight assessment.

The 6MWT and externally paced incremental SWT may be of value. Baseline values do not reliably predict in-flight hypoxaemia in a number of respiratory conditions^{1 4 33 34 44 49–51} but changes in SpO₂ during 6MWT and SWT may correlate with HCT outcome in COPD, ILD and chest wall deformity.^{30 38 44 45} Walk tests cannot predict the in-flight oxygen flow rate required, but they may help inform the decision as to who needs further assessment.

A walk test is not always practical. Data from one small study in COPD suggest that MRC scores may help predict the likelihood of exercise desaturation.⁵² From this it appears that patients with COPD, MRC score 1 or 2 and resting oxygen saturations >95% do not usually need further testing before air travel. If there are still concerns, a walk test may help decide whether HCT is required. In those with COPD who do undergo 6MWT or SWT and do not desaturate below 84%, in flight oxygen should not be required and they should not need HCT.

If resting oxygen saturations are SpO₂ 92%–95% and they desaturate <84% but have no evidence of CO₂ retention, data from Edvardsen *et al*³⁰ suggest it is reasonable to recommend in-flight oxygen at 2 L/min without proceeding to HCT. Patients in whom there are concerns about hypercapnia should proceed to HCT.

Data are much more limited in restrictive disease, including ILD, and baseline SpO₂ does not appear to predict outcome. In general, it seems reasonable to suggest that if baseline saturations are >95% at rest and there is no desaturation below 95% on 6MWT or SWT, HCT should not be required. Those with ILD and TLco ≤50% of predicted and PaO₂ ≤9.42 kPa are likely to need in-flight oxygen or HCT. If there are no concerns about hypercapnia it may be reasonable to recommend 2 L/min without recourse to HCT. If there are concerns about CO₂ retention, titration HCT will be required to determine the oxygen flow rate.

Hypoxic challenge testing

HCT is performed using an inspired gas mixture containing 15% oxygen, which gives an approximate similar inspired oxygen tension (PO_2) to breathing air at the maximum allowable cabin pressure altitude (2438 m or 8000 ft).^{53,54} HCT is usually performed in a specialist respiratory physiology unit. The provision of a 15% oxygen gas mixture can be achieved using one of the methods described in online supplemental appendix B.

The closest approximation to aircraft cabin conditions entails exposure to simulated altitude in a hypobaric chamber, but such chambers are not available for clinical assessment. A reasonable substitute is the normobaric HCT, described by Gong *et al*⁵⁵ in patients with chronic airflow obstruction. This assesses the response to hypoxaemia achieved by breathing a hypoxic gas mixture at sea level. Various methods of hypoxic gas delivery produce equivalent results to tests in a hypobaric chamber or during real flights in adults with COPD.^{1,39,56–58} Data are limited in other conditions as well as for children and neonates.

The HCT is used to help decide whether passengers with respiratory disease need in-flight oxygen and at what flow rate. It does not assess fitness for air travel, despite its reputation as a 'fitness to fly' test. If healthcare providers give this impression in patient information, they must manage patient and carer expectations accordingly. A 'preflight oxygen test' is a more accurate description. Most patients do not require HCT as part of preflight medical assessment, and there should not be pressure on physicians to arrange, or healthcare professionals to perform, unnecessary HCT.

The physiological response to hypobaric hypoxia ($PaO_2 < 8$ kPa) is increased ventilation.⁵⁹ Alterations in respiratory pattern may adversely impact on lung mechanics,⁶⁰ which may be further impaired by gas expansion, reducing vital capacity and increasing residual volume.⁶¹ The increase in ventilatory drive is likely to be limited on commercial flights,⁶² but a modest increase in ventilation can exhaust an already reduced ventilatory reserve.^{16,60,63}

The usual consensus is to recommend in-flight oxygen if PaO_2 is predicted to fall below 6.6 kPa (50 mm Hg) or SpO_2 below 85% in flight. There is little high-quality evidence supporting these cut-off values, but this PaO_2 value ensures that SpO_2 remains above the steep portion of the oxyhaemoglobin dissociation curve.⁶⁴ Some authors consider 6.6 kPa to represent the lower safe limit for hypoxaemia,^{65,66} as PVR increases sharply in response to arterial pO_2 below this level,⁶⁷ with the potential for an acute increase in right ventricle afterload and right ventricular dysfunction.^{16,29} As many patients with COPD have cardiac comorbidity,⁶⁸ hypoxaemia in these patients could precipitate cardiac ischaemia; this is unlikely in those with stable disease in NYHA functional class I or II (no or mild limitation of physical activity).^{69,70} In the absence of new evidence to the contrary, the cut-off PaO_2 of 6.6 kPa during HCT appears reasonable.

HCT outcomes do not predict respiratory symptoms during air travel.^{71,72,73} Such symptoms do not appear to result directly from hypoxaemia,⁶² but from a combination of poor respiratory mechanics and reduced respiratory reserve impairing the response to hypoxaemia. Symptoms are more likely to occur in those with more severe breathlessness at sea level.^{4,72} Limited evidence suggests that those who desaturate during HCT and have previously experienced respiratory symptoms during air travel can avoid these by using in-flight oxygen.^{29,71} Symptoms may also result from anxiety regarding air travel (see section on hyperventilation and DB).

Patient selection for HCT

Those with stable respiratory disease without history of air travel intolerance, normal resting and exercise SpO_2 at sea level and no significant cardiac comorbidity, are unlikely to need in-flight oxygen and should not require HCT. Those who have had HCT in the past should not need it repeated unless their clinical condition has changed. The patient's plans should, however, be discussed with the patient's respiratory physician, paediatrician or specialist nurse.

Those already using LTOT will need in-flight oxygen. Ideally, the flow rate required at cruising altitude should be determined using HCT. If HCT is not readily available and there are no concerns about hypercapnia, passengers already on LTOT should be advised that they will need a flow rate 2 L/min greater than their baseline flow rate. This should be sufficient to compensate for the relative hypoxia at normal cabin altitude. However, current POCs do not routinely offer continuous flow rates above 3 L/min, and a pulse-dose delivery mode at higher levels may not always be suitable.⁷⁴

As noted above, it is not practical for all patients with COPD who want to fly to undergo 6MWT. Respiratory physicians may however wish to consider 6MWT if there has been a significant change in the patient's condition since the last assessment, or in new patients previously unknown to the service. Those who desaturate below 84% may then be referred for HCT at the discretion of the respiratory physician.

Some data are available in smaller numbers of patients with restrictive lung disease, but there is currently no consensus regarding the best walk test or cut-off values. In a study of 14 patients with primary thoracic scoliosis, Bandyopadhyay *et al* found that resting $SpO_2 > 95\%$ did not accurately identify those who do not desaturate during HCT, and recommend a low threshold for performing HCT on patients with thoracic scoliosis.⁴⁴ Likewise, in a study of 13 patients with OHS, baseline SpO_2 did not predict HCT outcome.⁴⁹ In a study including 42 patients with ILD and 20 with extra-pulmonary restriction³⁵ before and after '2 min of moderate exercise', Ling *et al* proposed that a postexercise SpO_2 of no less than 95% could be used to exclude the need for HCT. Further research is required to determine the most appropriate assessments for patients with a variety of restrictive lung diseases, including which (if any) can reliably eliminate the need for HCT.

Clinical practice points: patient selection for HCT

See figures 1 and 2

The following patients should not require HCT

- ▶ Those with stable disease who have previously undergone HCT (no recent hospital admissions, exacerbations, or significant changes to treatment).
- ▶ Patients with COPD with baseline $SpO_2 \geq 95\%$ and either MRC score 1–2 or desaturation to no less than 84% during 6MWT or SWT, should be able to travel without in-flight oxygen.
- ▶ Those with previous significant intolerance to air travel, such as mid-air emergency oxygen or diversion. These should have in-flight oxygen available at 2 L/min provided there is no history of hypercapnia.
- ▶ Preterm infants who have not reached their due date at the time of travel, as testing is not a reliable guide of oxygen requirement in these infants. These should have in-flight oxygen available, delivered at 1–2 L/min if they develop tachypnoea, recession, or other signs of respiratory distress.

HCT should be considered for the following

- ▶ Patients with COPD with resting SpO₂ ≤95%, MRC score 3 or greater, or desaturation to <84% on 6MWT or SWT, and in whom there are concerns about hypercapnia
- ▶ Infants and children with a history of neonatal respiratory problems, or existing severe chronic lung disease including those with FEV1 persistently <50% predicted (see page 7).
- ▶ Adults and children with severe asthma, evidenced by persistent symptoms and/or frequent exacerbations despite optimal treatment (see BTS/SIGN Asthma Guideline⁷⁵) regardless of resting sea level SpO₂.
- ▶ Patients with ILD in whom SpO₂ falls to <95% on exercise, and whose resting sea level PaO₂ is ≤9.42 kPa or whose TLCO is ≤50%.
- ▶ Those with severe respiratory muscle weakness or chest wall deformity in whom FVC is <1 L.
- ▶ Those with existing or previous hypercapnia and those at risk of hypercapnia, including those taking medication(s) which can cause respiratory depression.
- ▶ Patients with a history of type 2 respiratory failure already on LTOT at sea level. However, if there is no evidence of hypercapnia, it seems reasonable to recommend an increase in flow rate by 2 L/min in-flight, provided the equipment can provide it (see Appendix A).

Clinical practice points: HCT results

- ▶ PaO₂ ≥6.6 kPa (≥50 mm Hg) or SpO₂ ≥85%: in-flight oxygen not required.
- ▶ PaO₂ <6.6 kPa (<50 mm Hg) or SpO₂ <85%: in-flight oxygen recommended.
- ▶ Where required, titrate oxygen to maintain PaO₂ ≥6.6 kPa or SpO₂ ≥85% in adults, SpO₂ 90% in children aged 1 year or more.

Air travel may be contraindicated in infrequent cases when supplementary oxygen, at the flow rate needed to maintain PaO₂ ≥6.6 kPa or SpO₂ ≥85%, causes significant changes to pH and pCO₂. The 2015 BTS Guidelines for Home Oxygen Use in Adults¹⁹ consider that a pH <7.35, and a PaCO₂ increase >1 kPa from baseline (within 20 min) is significant. Specialist respiratory physicians should use their discretion to determine the risk in individual cases and advise accordingly. Where hyperventilation is suspected, especially in response to anxiety rather than hypoxaemia, results should be interpreted with caution as there is a risk of false negative results.⁷⁶

HCT methods

These are described in Appendix B.

Exertion on board

Studies in adults with COPD^{33 77 78} or CF⁷⁹ have shown that patients can develop profound hypoxaemia when exercising under hypoxic conditions, whether on board a commercial aircraft at cruising altitude or during HCT. This has been reported in patients whose HCT results would otherwise not warrant oxygen. In some cases, PaO₂ values as low as 3.9 kPa have been recorded.^{33 78}

The combination of further hypoxaemia and increased ventilatory demand from exertion while flying may challenge those already approaching the limits of their respiratory reserve. It therefore seems prudent to recommend that passengers with significant respiratory limitation, regardless of whether they travel with in-flight oxygen, should request an aisle seat near a toilet to avoid long periods of walking.^{1 29 80} Passengers should

keep active by undertaking seat-based exercises and/or standing at intervals if flight conditions permit.

Patients who cannot tolerate withdrawal of supplemental oxygen for even a short period of time should not travel by air, as there will be periods of time when oxygen cannot be supplied. POC use below 10 000 ft may in some circumstances be prohibited by cabin crew. The reduction in cabin pressure between an aircraft taking off and reaching 10 000 ft is small (10%) and unlikely to have any clinical impact on those who do not usually require oxygen at rest at sea level. Aircraft descent may however take longer than ascent, and the time to landing may be less predictable.

Disease/condition-specific advice

Chronic airflow obstruction including asthma and COPD

Most adults and children with well-controlled mild or moderate airflow obstruction and no other co-morbidities should have no problem with commercial air travel, but they should be prepared for the possibility of an exacerbation of their condition. Air travel presents a theoretical risk of bronchospasm because of mucosal water loss due to low cabin humidity.

Cigarette smokers are at a physiological disadvantage during exposure to altitude.⁸¹ Every opportunity should be taken, when reviewing travel plans, to take a smoking history and offer brief intervention and smoking cessation referral as appropriate.

Asthma

While asthma is prevalent and has the potential to be life-threatening, most episodes are not.^{82 83}

Most passengers with asthma will have relatively mild disease and do not require HCT. HCT should however be considered for those with severe asthma, regardless of baseline sea level oxygen saturation. In a retrospective study of 37 adults with severe asthma (as defined in the BTS/SIGN Asthma guideline⁷⁵) undergoing HCT, two-thirds who fulfilled the criteria for in-flight oxygen on HCT had baseline sea level oxygen saturations of >95%.⁸⁴

The role of HCT has not been studied in children with severe stable asthma. A study in 51 children aged 2–12 years requiring transient oxygen therapy during an acute asthma attack (SpO₂ <92%) showed that although 5% failed HCT within 24 hours of discontinuing oxygen therapy, all passed the HCT when retested at 48 hours.⁸⁵

Food allergy affects up to 8.5% of children and adults with asthma,⁸⁶ and asthma is a risk factor for severe or fatal anaphylaxis.⁸⁷ Appropriate precautions for those affected include wiping tray tables and hands, informing the airline beforehand and the cabin crew of allergies, and not eating during flights or bringing known 'safe' foods from home.⁸⁸

Clinical practice points

- ▶ The patient's condition should be optimised before travel, with attention paid to inhaler technique and smoking cessation referral as required.
- ▶ All medications and spacer devices should be carried in hand luggage to mitigate the risk of lost or missing hold baggage.
- ▶ Emergency medications, including salbutamol inhalers and spacers, must be immediately accessible.
- ▶ Individuals prescribed epinephrine auto-injectors should have them readily available.
- ▶ For acute exacerbations on board, the passenger's own bronchodilator inhaler should be given, with a spacer if needed.

- ▶ The passenger should alert the cabin crew if symptoms do not respond rapidly to use of the inhaler, or if they recur after a short interval.
- ▶ If the passenger does not have their own inhaler with them, or if it is inaccessible, the airline may carry an inhaler in the emergency medical kit. Spacers are not commonly available.
- ▶ Those with severe asthma should consult their respiratory specialist beforehand and consider taking an emergency supply of oral corticosteroid in their hand luggage in addition to their usual medication.
- ▶ Passengers with severe asthma are advised to carry copies of their asthma management plan and/or relevant clinic letters. Information can be held securely as scanned copies on a mobile phone, or on a digital platform such as the NHS App.
- ▶ Food allergy affects up to 8.5% of children and adults with asthma and asthma is a risk factor for severe or fatal anaphylaxis. Appropriate precautions for those affected include wiping tray tables and hands, informing the airline beforehand and the cabin crew of allergies, and not eating during flights or bringing known 'safe' foods from home.

Chronic obstructive pulmonary disease

Patients with COPD planning air travel need careful evaluation, not only because of their respiratory disease, but also because of their high levels of comorbidity.^{71 89}

Respiratory symptoms in those with COPD are common during air travel, but Edvardsen *et al* have shown that HCT does not predict respiratory symptoms during air travel in patients with moderate to very severe COPD.⁷¹ They suggest that exacerbation of comorbidities such as cardiovascular disease (the most common cause of death in COPD) is the most threatening consequence of severe hypoxaemia. This is consistent with data showing a risk of cardiac arrhythmias and ischaemic chest pain in patients with COPD unable to respond to the physiological stressors of air travel.^{55 70} Work by Robson *et al* shows that resting sea level saturations alone do not predict HCT outcome.²⁸

Spirometry does not reliably predict hypoxaemia or complications in COPD.²⁹ It seems prudent to avoid air travel within 6 weeks of an exacerbation although there are few data to support this recommendation. Patients with COPD are at greater risk of VTE as a direct consequence of the underlying condition, as well as after an exacerbation. They should be advised accordingly, especially if planning longer flights when the risk is further enhanced (see section on VTE).^{90–92} See Figure 1.

Clinical practice points

- ▶ The patient's condition should be optimised before travel, with attention paid to inhaler technique and smoking cessation referral where appropriate.
- ▶ All medications and spacer devices should be carried in hand luggage to mitigate the risk of missing hold baggage.
- ▶ Emergency medications, including salbutamol inhalers and spacers, must be immediately accessible.
- ▶ For acute exacerbations on board, the passenger's own bronchodilator inhaler should be given, with a spacer if appropriate.
- ▶ Passengers with severe COPD are advised to carry a copy of their COPD management plan and/or relevant clinic letters. This information can be held securely as scanned copies on their mobile phone. A history of previous pneumothorax or bullous lung disease necessitates assessment by a respiratory specialist to determine the potential risk of complications from reduced cabin pressure.

- ▶ Patients with COPD are at greater risk of VTE as a direct consequence of the underlying condition, as well as after an exacerbation. They should be advised accordingly, especially if planning longer flights when the risk is further enhanced.
- ▶ Patients requiring long-term oxygen therapy should also plan for oxygen supplementation at their destination (see online supplemental appendix 1).
- ▶ Wherever possible, those who have had a recent exacerbation of their condition should not fly until their condition is stable and use of reliever therapy has returned to their usual baseline. If their condition deteriorates while overseas, medical advice should be sought before undertaking the return flight.

CF (adults and children)

The risks associated with air travel are greater for those with CF than for healthy individuals.⁹³ This is despite the fact that people with CF have been shown to tolerate PaO₂ values below 6.6 kPa (50 mm Hg) for several hours without cardiac decompensation or cerebral symptoms⁹⁴; do not usually have cardiovascular comorbidities; and are generally younger than patients with other respiratory conditions. Hypoxaemia results mainly from ventilation/perfusion mismatch attributable to chronic inflammation and mucus plugging. It is not clear which physiological values measured at sea level best predict hypoxaemia or complications during flight.

In 1 study of 30 adults with CF undergoing HCT, four fulfilled the study's criteria for supplemental oxygen (PaO₂ <6.6 kPa) at rest and a further 11 dropped below this threshold while walking slowly. Variables obtained during CPET (including SpO₂ and PaO₂) showed a stronger correlation with arterial oxygen tension (PaO₂) during HCT than baseline SpO₂ or spirometry.⁷⁹ However, in children with CF the sensitivity and specificity of preflight HCT have been reported as 20% and 99% (using a cut-off of SpO₂ <90% during HCT with FiO₂ 0.15), compared with 70% and 96% for spirometry (cut-off FEV₁ <50% predicted).⁹⁵ Combining spirometry and HCT increased sensitivity to 80%. Spirometry may, therefore, usefully predict who may desaturate during flight, and a cut-off of FEV₁ 50% has been used to recommend HCT.

Passengers with CF should practise good hand hygiene using soap and water or an alcohol-based hand gel, and avoid touching their face, particularly after touching arm rests, food trays or toilet doors to minimise risk of infection. These measures are included within recommendations from the European Centres of Reference Network for Cystic Fibrosis project, endorsed by the European Cystic Fibrosis Society.⁹³ These also advise checking the relevant airline policy and levels of CF healthcare provision at the proposed destination before travel (see online supplemental appendix 1).

Clinical practice points

- ▶ All medications and spacer devices should be carried in hand luggage to mitigate the risk of missing hold baggage.
- ▶ Patients with CF under the age of 6 are likely to be well enough to fly at the paediatrician's discretion.
- ▶ In those with CF who are old enough for spirometry and whose FEV₁ is <50% predicted, HCT is recommended. If SpO₂ falls below the 90% cut-off, as outlined above, in-flight oxygen is advised.
- ▶ In children with chronic lung disease able to perform spirometry whose FEV₁ is consistently <50% predicted, HCT should be considered. This includes children with CF and non-CF bronchiectasis. Children with chronic lung disease who are too young to reliably perform spirometry

should have a clinical assessment of assess disease severity and their likely tolerance of hypoxia. For children with CF disease is rarely severe enough to severely compromise lung function at this age.

Non-CF bronchiectasis

Passengers with bronchiectasis should not necessarily be discouraged from flying, but air travel can pose challenges.

Clinical practice points

- ▶ Regular airway clearance is essential for those dealing with overproduction of mucus.
- ▶ Advice from a respiratory physiotherapist on adapting airway clearance techniques should be sought for long-haul flights.
- ▶ Portable nebulisers and PEP devices may be considered, but use of these devices in-flight must be approved by the airline before travel.

Interstitial lung disease

Like individuals with airflow limitation, patients with ILD, including pulmonary fibrosis, respond to hypoxaemia at altitude with increased heart rate and minute ventilation. In severe disease the ability to increase minute ventilation is limited and the resulting hypoxaemia may be marked. However, unlike COPD, where many patients appear to be able to tolerate marked hypoxia,⁶⁵ patients with ILD may have acute or subacute disease and be less able to withstand marked hypoxia. There are fewer relevant studies available in ILD, and patient numbers are smaller than in COPD studies.

Two studies in patients with ILD (n=15 and 10, respectively) have shown that sea level oxygen saturations do not reliably predict HCT outcome, and that oxygen saturations fall significantly after light exercise performed under conditions of normobaric hypoxia.^{73,96} These findings are consistent with those from the UK Flight Outcomes Study,⁴ a prospective observational study of 431 patients including 186 with ILD. This showed that neither FEV1 nor sea level SpO₂ reliably predict desaturation at altitude, and that patients with ILD were more likely than others to require unscheduled healthcare for respiratory events within 4 weeks of air travel.

In a study including 15 patients with ILD, Martin *et al* found that predictive equations overestimated the need for in-flight oxygen in patients with ILD, as they did for those with COPD and CF.⁹⁷

More recently, Barratt *et al* examined the predictive value of various parameters for HCT outcome in 106 ILD patients (69 with IPF).⁹⁸ Only the combined parameters of TLCO >50% predicted and sea level PaO₂ >9.42 kPa independently predicted a successful HCT outcome. From analysis of a subset of 88 patients with a complete dataset available the authors propose a new preflight algorithm for patients with ILD with a sensitivity of 86% and specificity of 84%. In patients with both sea level PaO₂ ≤9.42 kPa and TLCO ≤50% predicted, in-flight oxygen is recommended without recourse to an initial diagnostic HCT. HCT for titration of the oxygen flow rate required on board is still advised. For patients in whom either TLCO ≤50% or PaO₂ ≤9.42 kPa, diagnostic HCT is advised. This promising approach requires further validation in a larger, prospective cohort of patients with ILD, preferably supported by patient reported outcomes from actual flight(s).

Clinical practice points

- ▶ In patients with comorbidity, including PH and/or cardiovascular disease, attention should also be paid to the impact of air travel on these conditions.
- ▶ Physicians may wish to consider HCT in those whom SpO₂ falls to <95% on exercise, and/or in those in whom either TLCO ≤50% or PaO₂ ≤9.42 kPa (if available).
- ▶ Patients with TLco <50% of predicted or PaO₂ ≤9.42 kPa are likely to need in-flight oxygen. If there are no concerns about hypercapnia it may be reasonable to recommend 2 L/min without recourse to HCT. In those in whom there are concerns about CO₂ retention, titration HCT is advised to determine the oxygen flow rate.

Thoracic surgery and other interventional procedures

There is no high-quality evidence in this area and further research and/or data collection are needed. The following are suggested time periods before which a medically unaccompanied commercial flight can safely be undertaken after the specific thoracic interventions described below. The advice is conservative. Shorter recovery periods may be appropriate in individual cases, but only if approved by the doctor/surgeon carrying out the procedure. It is also important to note that the potential risks of travel are not just those associated with a postprocedure pneumothorax, but include wound infection and pain, which could require medical attention at destination and would need approval by the travel insurer.

Thoracic surgery, including VATS procedures

In the absence of published evidence, we advocate a conservative and safe minimum time interval, with the caveat that flying sooner after such procedures may be possible and/or desirable, but that this should be agreed with the surgeon and discussed with the airline. At least two UK centres independently advise against non-essential air travel for 4 weeks after removal of drains (Jon Naylor, personal communication). If air travel is essential, a minimum delay of 2 weeks is advised, depending on the type of surgery and the surgeon's advice.

Clinical practice points

- ▶ The opinion of the surgeon or interventionalist should be obtained before the patient travels by air. Patients, professionals, and their carers should be aware that this may result in a delay of 4 weeks for non-essential air travel and 2 weeks for essential air travel.
- ▶ Careful clinical assessment of the patient is required. This should include consideration of their baseline status including comorbidities, SpO₂, postprocedure complications such as infection and/or pain, flight duration and destination.

Percutaneous lung biopsy, pleural procedures (including thoracocentesis, medical thoracoscopy and insertion of indwelling pleural catheter)

A North American study of 179 patients, who between them underwent 183 percutaneous transthoracic needle biopsies, suggested that air travel was safe within 24 hours of procedure, even in the 65 patients (35%) who developed a small, stable postbiopsy pneumothorax.⁹⁹ Fifty (77%) of them flew within 4 days of the final postbiopsy chest radiograph. During a brief telephone survey after the flight, 14 (8%) reported worsening of pre-existing respiratory symptoms or new respiratory symptoms. There were no reported events requiring in-flight medical attention or flight diversion. These were, however short, internal North American flights over land, where diversion is relatively

straightforward if required. The situation for a UK-based patient travelling on a long-haul flight to the Middle East, USA, Far East or Australasia is quite different.

Clinical practice points

- ▶ The opinion of the interventionalist should be obtained before the patient travels by air.
- ▶ Careful clinical assessment of the patient is required. This should include consideration of baseline status including comorbidities, SpO₂, postprocedure complications such as infection or pain, flight duration and destination.
- ▶ Patients with no pneumothorax seen on the postprocedure chest X-ray should wait for 1 week before air travel.
- ▶ Patients with a pneumothorax seen on the postprocedure chest X-ray should wait for 1 week after resolution on chest X-ray before air travel.

'Trapped lung' after drainage of pleural space

Only very limited data are available, from a report of two patients with a small chronic pneumothorax.¹⁰⁰ This suggests that such patients may be able to travel safely by air, but require thorough clinical assessment, CT imaging and HCT as a minimum beforehand.

Clinical practice points

- ▶ The opinion of the interventionalist should be obtained before the patient travels by air.
- ▶ Patients should be assessed carefully and advised on a case-by-case basis.
- ▶ Patients should be clinically stable before air travel.

Bronchoscopic procedures

The risks associated with air travel are not only those of a possible pneumothorax, but also the effects of sedation, exacerbation of pre-existing or new symptoms such as cough, hoarse voice haemoptysis and dyspnoea, respiratory infection and the consequences of arrhythmias observed during the procedure.

Clinical practice points

- ▶ The opinion of the interventionalist should be obtained before the patient travels by air.
- ▶ Patients should be clinically stable before they travel.
- ▶ After interventional bronchoscopy including TBNA, TBB, EBUS and endobronchial valve insertion, those with no pneumothorax seen on the postprocedure chest X-ray should wait for 1 week before air travel.
- ▶ After interventional bronchoscopy including TBNA, TBB and EBUS, those with a pneumothorax seen on the postprocedure chest X-ray should wait for 1 week after resolution on chest X-ray before air travel.

Pleural disease

Pleural effusion

Patients with stable pleural disease and normal resting oxygen saturations should be able to fly without further precautions. Those who have indwelling long-term drainage catheters should be reminded that the manufacturers do not advise air travel. Those who choose to travel should be encouraged to take a supply of drainage bottles for their time away.

In those with a recent onset pleural effusion, investigation should be delayed if air travel is planned within 2 weeks, since intervention may increase the risk of pneumothorax. The risk of delaying investigation should be discussed with the individual to determine whether travel plans can be modified.

Pneumothorax

The prevalence of in-flight pneumothorax in passengers with existing lung disease appears low overall, being zero in the UK Flight Outcomes Study.⁴ It increases, however, in those at increased risk: 3.6% in a study of 276 patients with LAM¹⁰¹; and 9% within 1 month of air travel in a retrospective survey of 145 patients with BHD syndrome.¹⁰²

Most individuals with an untreated, closed pneumothorax should not travel by air. In exceptional cases where the pneumothorax is long-standing and thought to present a low risk, secondary care evaluation is strongly advised before travel.

In individuals with a treated pneumothorax, exposure to altitude poses a risk of recurrence. The 2010 BTS Pleural Disease guidelines state that patients '...should be cautioned against commercial flights ... until full resolution of the pneumothorax has been confirmed by a chest X-ray'.¹⁰³ These guidelines state that patients should wait a week after pneumothorax resolution before flying. There is limited, more recent evidence to suggest that in the case of traumatic pneumothorax, air travel as early as 72 hours after chest drain removal with full lung inflation may be safe.¹⁰⁴ A prospective observational study of 20 patients with a small residual traumatic pneumothorax, exposed to hypobaric hypoxia for 2 hours suggested no significant clinical effects despite expansion of up to 171%.¹⁰⁵ The data should, however, be interpreted with caution given the small numbers involved, the small size of the pneumothorax in each case, and the limited duration of hypobaric exposure. They are not sufficiently robust to justify overriding current BTS guidance.

In those who have undergone thoracotomy and surgical pleurodesis, the recurrence rate is so low that no subsequent restriction on travel is necessary.¹ The recurrence rate has been reported to be four times greater after video-assisted thoracoscopy,¹⁰⁶ suggesting that this procedure may not be as definitive. The risk of recurrence is greatest in those with pre-existing lung disease, cigarette smokers and taller men.¹

Clinical practice points

- ▶ Passengers should not travel by air until 7 days after full resolution on chest X-ray.
- ▶ Those at higher risk of recurrent pneumothorax should be advised accordingly.
- ▶ Higher-risk groups, including those with cystic lung disease such as LAM and BHD syndrome, should be advised accordingly.
- ▶ Patients with trapped lung and a chronic air space thought to present a low risk should be evaluated in secondary care before travel.

Respiratory tract infections

Upper respiratory infection including otitis media and sinusitis

During air travel with acute infection of the upper airway, the main risks are unpredictable, but may reflect previous experience. They are of pain and potential rupture of the tympanic membrane. Those with significant symptomatic viral upper respiratory tract infection may wish to delay travel because of the risk of pain and disseminating infection to others.

Barotrauma, characterised by otalgia, is a consequence of inability to equilibrate the pressure differential between the external and middle ear. This is usually more severe during landing than take-off. Most passengers, including older children, can equilibrate the pressure through yawning, swallowing, chewing or a Valsalva manoeuvre (eg, pinching the nose and blowing). Infants and young children may be unable to perform these manoeuvres, but swallowing may be encouraged by

drinking. It is also more frequent when the child is awake and/or crying.

It has been estimated that 10% of adults and 22% of children may have changes to the ear drum after a flight, although perforation is rare and symptoms usually resolve spontaneously.^{107 108}

Historically, oral (and to a lesser extent topical) decongestants have been recommended for adults with risk factors for sinus or middle ear barotrauma.¹ The evidence is very weak, and there is no evidence in children. Treatment with intranasal steroids (commenced at least a week before the flight) can however improve symptoms, as for inflammatory rhinosinusitis. After an episode of acute otitis media, patients are usually advised not to fly for 2 weeks¹⁰⁷

Clinical practice points

- ▶ In passengers who develop sinus barotrauma after flying, it may be helpful to consider topical and oral decongestants as well as appropriate analgesia. Prolonged use of decongestants is not advised owing to the risk of rebound congestion on withdrawal.
- ▶ If there is an allergic component, intranasal steroids used for a week prior to travel, and/or oral corticosteroids may be considered.
- ▶ Symptoms and signs of barotrauma should have resolved before flying again. This usually takes between 1 and 6 weeks.
- ▶ After an episode of acute otitis media, patients are usually advised not to fly for 2 weeks.

Viral infections

Although viral infections may be transmitted on board, as in any environment where people are in proximity for prolonged periods, available data suggest this is not common on modern commercial aircraft. This may reflect lack of face-to-face contact, the barriers afforded by seat backs, and the characteristics of cabin airflow on board, which is not front to back. Viruses are within the particle size range captured by HEPA filters on modern commercial aircraft, which are like those used in hospitals. Transmission by droplet spread, including via fomites, is applicable to all environments.^{100 101} This may be reduced by passengers wearing masks, frequent use of hand sanitiser and disinfectant wipes for hard surfaces, and by regular deep cleaning of the aircraft cabin. The risk of infection in airport facilities on departure, during stopovers, and on arrival should also be considered. More general hygiene practices, such as handwashing and covering the mouth and nose when coughing or sneezing, have also been shown to reduce spread of viral infections.^{109 110}

Some respiratory viral infections may be more infectious than others. A review of passengers on a flight carrying a confirmed case of SARS in 2003 reported 16 cases of SARS developing in fellow passengers,¹¹¹ but it seems likely that affected individuals were in close proximity in the airport lounge, so transmission may have occurred before boarding. To date there is just one reported case of possible aircraft transmission of COVID-19,¹¹² but the literature is clearly evolving.

The principal public health concern around air travel is the role it plays in carrying infected persons (who may be asymptomatic and are not always contagious) long distances within a short space of time, with the associated risk of disseminating novel contagious disease to new locations. This has been especially evident during the COVID-19 pandemic. Special attention should therefore be paid to the clearance of people wishing to fly who have respiratory tract symptoms during outbreaks of such infections. At any time, and not just during outbreaks of serious infectious respiratory disease, airport screening measures may be

implemented and travellers with a fever can be refused boarding by the airline. In cases of serious epidemics and/or pandemics such as MERS and COVID-19, even urgent travel may be prohibited. The Centers for Disease Control and Prevention website has regular updates on air travel (www.cdc.gov). The 2020 BTS COVID-19 Statement on Air Travel contains practical advice for potential passengers with lung disease during the COVID-19 pandemic.¹¹³

Clinical practice points

- ▶ Patients with highly contagious infections including measles, chickenpox, mumps, SARS, MERS or COVID-19 should not be allowed to travel until they are considered non-infectious.
- ▶ Passengers should familiarise themselves with current national and international regulations regarding air travel, which should always be observed.

Tuberculosis

WHO provides comprehensive information about the risk of air travel with TB.¹¹⁴ Risk is determined by two factors: whether acid fast bacilli are present on smears of respiratory samples, or a sputum smear is culture positive; and whether drug resistance is present. Patients with sputum smear or culture positivity are considered potentially infectious.

Clinical practice points

- ▶ Smear positive patients must not fly until they have provided two smear negative samples on treatment.
- ▶ Those starting treatment for pulmonary TB, where not all the information is yet available, should not travel by air for the first 2 weeks.
- ▶ For those who are smear negative and have a fully sensitive organism, treatment would be expected to render them non-infectious after 2 weeks.
- ▶ For patients with MDR/XDR TB, travel is prohibited until two negative culture samples have been produced and there is clinical evidence of improvement on treatment.
- ▶ Extrapulmonary TB does not usually warrant additional precautions before air travel.

Pneumonia

Patients suffering from acute lobar bacterial pneumonia present a low risk to other passengers. They are, however, more likely to experience in-flight desaturation during flight.

Clinical practice points

- ▶ All but essential travel should be postponed for 7 days in those who have reduced baseline sea level SpO₂ (<94%).

OSAS and OHS

The most recent available guidance states that for patients with OSAS, the potential risks during commercial airline travel are worsening hypoxaemia when asleep, and exacerbation of jet lag with potential adverse effects on driving.¹

Data are sparse regarding risks for passengers with OSAS during air travel. Some data suggest there is a risk of cardiovascular and other adverse events in this group when staying at high altitude destinations. Hypobaric hypoxia can promote central apnoeas in addition to obstructive events, which may cause tachycardia, cardiac arrhythmia and systemic hypertension.¹¹⁵ It is not, however, clear how quickly this response develops, and therefore whether the findings are relevant to air travel.

Using hypobaric chamber simulation testing, studies have shown that there is an association between hypoxaemia, decreased sleep time and an increased frequency of hypopneas

for patients with OSAS who are acutely exposed to high altitude.¹¹⁶ There are further adverse effects on sleep and OSAS if alcohol¹¹⁷ or sedatives¹¹⁸ are taken.

Many patients with OSAS are already established on CPAP. Some studies have shown that patients with OSAS have lower oxygen saturations at baseline and at cabin altitude simulation than normal subjects.¹¹⁹ The changes are more marked in those with severe OSAS. Use of CPAP at altitude is associated with decreased central sleep apnoea and increased sleep efficiency.¹¹⁶

Consideration must be given to the whole journey including the return flight. This is especially important if the flight involves an overnight element and patients expect to drive the next day. Studies have identified that not using CPAP for one night during the flight increases the risk of drowsiness at destination the following day.¹²⁰

Careful planning is required. A retrospective survey of 394 patients who undertook air travel with CPAP reported that over a third encountered problems with their equipment, power cord, adapter or transport of the CPAP machine.¹²¹ These findings highlight the need for clinical teams to understand the logistics so that they can support safe patient travel (see Appendix A).

In summary, the potential physiological risks for this group include cardiac stress; increased frequency of hypopnoeas; possible central apnoeas; hypoxaemia and exacerbation of jet lag.

There are no data relating specifically to air travel in OHS, which is considered a restrictive disorder. For these patients, physicians should refer to guidance around the use of NIV in those with respiratory muscle and chest wall disorders.

Clinical practice points

- ▶ Daytime flights are advised wherever possible.
- ▶ The patient should be advised to carry their CPAP device as hand luggage, and a hospital letter to advise that the patient uses CPAP.
- ▶ Careful planning and preparation are required, and use of the patient's own CPAP device is advised.
- ▶ Alcohol and sedatives should be avoided in the 12 hours before, and during, airline travel.
- ▶ Patients should use their CPAP device on board if they are travelling overnight, and avoid sleeping during daytime flights.
- ▶ Consideration should be given to device settings and whether adjustment is required for operation at altitude.
- ▶ Airline approval for carriage and use of device, including battery specification, must be gained before travel.
- ▶ Consideration should be given to the whole journey. If driving is required the following day, an overnight stay at destination may be advisable. Patients are advised to refrain from driving if tired and sleepy.

Respiratory muscle and chest wall disorders

There is little good evidence to guide decision-making around the need for oxygen or NIV during air travel for patients with severe extrapulmonary restriction resulting from chest wall disorder or respiratory muscle weakness. One case report suggests that a long-haul flight may have precipitated a first episode of PH and right heart failure requiring intubation and ventilator support in a man aged 59 with congenital kyphoscoliosis and apparently stable cardiorespiratory function before travel. FVC was documented as 0.98 L on recovery.¹²²

Some work has been conducted to understand which patients require HCT. The authors of a study of 21 adults with idiopathic kyphoscoliosis or neuromuscular disease¹²³ concluded that

those with FVC <1 L, even with resting SpO₂ >95%, are likely to desaturate significantly at cabin altitude. In some restrictive conditions, for example, bulbar MND, FVC is difficult to reproduce. Walk tests may aid decision-making in patients with scoliosis,³⁵ but may also be inaccessible to those with MND and similar conditions where spirometry is a challenge.

Since the 2011 BTS recommendations,¹ several studies have tried to identify factors that may predict the need for in-flight oxygen for patients with neuromuscular disease. One study aimed to identify parameters that predict HCT outcome in 40 patients with MND. Baseline PaCO₂ was the only independent predictor of hypoxaemia during HCT.¹²⁴ This appears to be supported by a more recent study examining baseline PaCO₂ as a predictor of HCT outcome.¹²⁵ Patients likely to fail HCT have a higher baseline PaCO₂, but the authors were unable to determine an absolute threshold PaCO₂ value that could identify patients needing in-flight supplementary oxygen.

Another study in 36 patients with MND examined baseline lung function as a predictor of hypoxaemia in response to altitude simulation.¹²⁶ The authors concluded that maximum inspiratory pressure (MIP) and sea level SpO₂ may help identify MND patients who will develop hypoxaemia at altitude. Despite the small numbers, none of the patients with an MIP >30 mm Hg or with sea level SpO₂ >96% desaturated below 85% during HCT. Preliminary data from a smaller study of 12 patients with MND suggested that sniff nasal inspiratory pressure (SNIP) may more accurately predict the risk of hypoxia during air travel in those with neuromuscular disease and respiratory muscle weakness.¹²⁷

While evidence to date addresses specific patient groups, the principles may be applied to any individual with a restrictive disorder resulting from respiratory muscle weakness or chest wall deformity. Further research on the value of FVC, PaCO₂, MIP and/or SNIP in predicting HCT outcome in this group is desirable. In the meantime, it seems reasonable to recommend that individuals with severe respiratory muscle weakness or chest wall deformity (FVC <1 L) should undergo HCT before air travel. Physicians should use their discretion for considering HCT if there are additional reasons for concern, such as a history of previous travel intolerance, hypoxaemia or hypercapnia.

In those with respiratory muscle weakness, the possibility of respiratory failure should also be considered. For patients established on NIV, further planning and advice are required to support the use of NIV during flight. If continuous flow oxygen cannot be provided by the airline or by POC, oxygen and NIV cannot be used simultaneously. A decision around whether NIV or supplementary oxygen is of greatest physiological importance to the patient is then required on an individual basis. The previous travel history, current clinical condition and the presence or absence of overnight travel should also be considered. (see Appendix B, table 2).

In summary, the potential physiological risk for patients with restrictive respiratory disease is respiratory failure resulting from inadequate ventilation. It is therefore essential to assess ventilatory requirements before deciding whether supplementary oxygen is required. The risk of respiratory failure must be understood and assessed before travel, and there are currently no absolute predictors to guide which patients are likely to require supplementary oxygen.

Clinical practice points

- ▶ HCT is recommended for all adult patients with FVC <1 L, pending further data, and may be considered in others

Table 2 Clinical practice points: Hypoxic challenge test (HCT) outcomes

PaO ₂ ≥ 6.6 kPa (≥ 50 mm Hg); SpO ₂ ≥ 85%	In-flight oxygen not required
PaO ₂ < 6.6 kPa (<50 mm Hg); SpO ₂ <85%	Repeat HCT with oxygen (flow rate and modality ideally the same as that to be given on board aircraft): <ul style="list-style-type: none"> ▶ Titrate oxygen to maintain PaO₂ ≥ 6.6 kPa or SpO₂ ≥ 85% ▶ Monitor pH and pCO₂ if there is a history of hypercapnia
Consider advising against air travel if pH falls to <7.35 and PCO ₂ increases by > 1 kPa (7.5 mm Hg) from baseline when PaO ₂ is maintained at ≥ 6.6 kPa or SpO ₂ ≥85%	

The use of arterial or capillary blood gas sampling is preferred if available. Blood gases are not routinely measured in children. Recommendations on pCO₂ and pH changes are based on the 2015 BTS guideline for home oxygen use in adults.¹⁹

thought to be at particular risk, including children with reduced FVC due to respiratory muscle or chest wall disorders.

- ▶ If patients are unable to perform spirometry reliably, a walk test may be considered as an alternative.
- ▶ Patients should be advised to take daytime flights where possible.
- ▶ Further planning and support are required for those established on NIV (see Appendix A).

VTE (DVT and PE)

Prevention of VTE during air travel

The risk of VTE during air travel appears low overall, and prophylaxis is unnecessary for most travellers. Prolonged travel (exceeding 6 hours) and/or the coexistence of another risk factor for VTE increase the risk. The incidence of symptomatic VTE has been estimated at 0.5% on flights over 12 hours, but asymptomatic rates may be higher.^{128–130} The reasons for the increased risk are not entirely clear. Potential contributory factors include prolonged immobility and dehydration, but these are not conclusively proven. Other risk factors for VTE such as obesity, recent surgery, pregnancy, malignancy and previous VTE all increase the overall risk for travel-related VTE and may necessitate additional prophylaxis.

General measures, including getting up and walking around where possible every 2–3 hours; ankle and calf exercises and avoidance of alcohol or sedating drugs; are advisable for most travellers. Although there is no conclusive evidence that flying causes dehydration, the fall in cabin humidity along with alcohol consumption and reduced fluid intake, may increase the risk on long haul flights. Remaining well hydrated is, therefore, advisable. Wearing graduated compression stockings during travel may reduce the incidence of deep venous thrombosis.¹³¹ Data are sparse regarding the method or duration of pharmacological prophylaxis, and recommendations rely on consensus expert opinion. Physicians may wish to recommend pharmacological prophylaxis for those at higher risk of VTE, for example an obese patient planning a flight exceeding 6 hours with a history of recent surgery. The risks of prophylaxis are thought to be low. There is limited evidence for LMWH as prophylaxis.¹³² There is no formally recommended dose, but enoxaparin 40 mg at a dose of 40 mg or weight based 1 mg/kg injected once 4–5 hours before the flight has been suggested.¹³² The use of factor Xa inhibitors is off-licence in this situation and currently has no evidence base.

Clinical practice points

- ▶ Limit the risk of dehydration with adequate fluid intake.
- ▶ Avoid alcohol.
- ▶ Keep mobile, if possible, by walking around or doing seat-based exercises once an hour.
- ▶ Consider graduated compression stockings (class 1 with 15–30 mm Hg).
- ▶ LMWH or a DOAC are advised for both outward and return long haul flights (long haul defined as flights of 6–12 hours) in high-risk patients including those with a history of VTE; local policy should be followed regarding liaison with primary care and/or haematology services to teach the patient how to administer the injection and dispose safely of the equipment. There is no formally recommended dose, but enoxaparin at a dose of 40 mg or weight based 1 mg/kg injected once 4–5 hours before the flight has been suggested.
- ▶ The prophylactic doses of the DOAC may also be used.
- ▶ All patients with a recent (<6 weeks) history of VTE, especially any who presented with significant right ventricular strain and decompensation should be reassessed before air travel.

Air travel after VTE

Although the risks of prolonged air travel and development of VTE are well known, there are fewer data on the risks associated with flying after a diagnosis of VTE.

A patient with a confirmed diagnosis of PE is highly likely to start anticoagulation, with the aim of preventing the formation of new deep venous thrombi and further PEs. There is a general acceptance that flying immediately after a diagnosis of PE/DVT should be avoided. It appears reasonable to assume that the sooner air travel occurs after a PE the greater the likelihood that hypoxic pulmonary vasoconstriction will exacerbate ventilation-perfusion mismatch and raise pulmonary pressures, affecting cardiac output.

Some authors, but not all, suggest that most clots are resolved after 14–21 days.¹³³ Consensus opinion is to delay air travel, if possible, usually for at least 2 weeks, although there are no concrete data to support a safe time interval. Clearly the risk-benefit ratio needs to be assessed if more urgent air travel is needed. Clot resolution depends principally on *in vivo* fibrinolysis. Consideration should be given to the severity of the initial presentation. It is good practice, before any proposed air travel, to reassess clinically a patient who has presented with significant right ventricular strain and decompensation.

The probability of recurrent VTE while anticoagulated is extremely low. Recovered, stable patients who remain on anticoagulation should be reassured accordingly and advised to follow the above general measures.

Clinical practice point

- ▶ Air travel should be delayed for 2 weeks after a diagnosis of DVT or PE.

Pulmonary hypertension

Data are sparse, and recommendations are largely based on expert consensus opinion. The concern in PH is the risk of hypoxia causing increased pulmonary arterial pressure and right ventricular strain. Most studies have employed HCT. They have shown that most patients with PH can tolerate this degree of hypoxia with minor increases in dyspnoea.¹³⁴ Furthermore, the effect on the right ventricle in one study has been shown to be minimal.¹³⁴ However, most of these studies only covered a short

time period.¹³⁴ Longer exposure to hypoxia on long haul flights may have more significant effects.

One study has monitored patients during commercial flights.¹³⁵ This showed that up to a quarter of patients with PH desaturate during short haul flights, with higher altitude, ambulation and longer flights correlating with desaturations. Most tolerated this well, with fewer than 40% of participants reporting symptoms. A larger questionnaire based retrospective study has also confirmed that in most patients with stable PAH, flight is well tolerated with minimal clinical effects.¹³⁶ Around half those surveyed travelled with supplementary oxygen.

Hypoxia reduces exercise capability; breathing oxygen-enriched air improves exercise capacity.¹³⁴ It therefore appears logical to give patients with impaired functional capacity supplemental oxygen on board the aircraft. Whether patients should have oxygen while walking around as well as when sitting is unknown; ambulatory oxygen on board presents obvious logistical challenges.

The 2011 BTS Recommendations advised that patients in NYHA WHO functional class 3 or 4 should have supplemental oxygen during air travel.¹ This recommendation is pragmatic rather than evidence based; and may result in over-prescribing of in-flight oxygen. One study suggests that more than double the number of patients would be recommended in-flight oxygen based on functional class rather than HCT outcome.¹³⁴

If HCT is not readily available and there are no concerns about hypercapnia, passengers already on LTOT should be advised that they will need a flow rate 2L/min greater than their baseline flow rate. This should be sufficient to compensate for the relative hypoxia at normal cabin altitude.

Clinical practice points

- ▶ Those in NYHA WHO functional class 3 or 4 are usually advised to have in-flight oxygen. If there is no evidence of hypercapnia it seems reasonable to suggest 2L/min by nasal cannulae. If there are concerns about hypercapnia, HCT should be considered if available.
- ▶ Those eligible for LTOT (sea level PaO₂ <8 kPa at rest on air) should have in flight oxygen at double the flow rate recommended at sea level, provided there is no evidence of hypercapnia.

Lung cancer and mesothelioma

When evaluating those with lung cancer or mesothelioma it is important to consider the nature and extent of their condition as well as their treatment. A pragmatic approach is to evaluate their risk of haemorrhage, pneumothorax, pleural effusion, VTE and any recent surgical and/or bronchoscopic interventions.

If taking medication, and particularly controlled drugs, patients must be aware of the appropriate documentation required for the countries they are visiting. Advance-planning is essential.

Clinical practice point

- ▶ Patients undergoing chemotherapy should not travel while they are at increased risk of infection or suffering from significant side effects, such as vomiting.

Hyperventilation and DB

There are few data on the implications of functional breathing disorders for air travel, whether DB, VCD or ILO. Asthma should not be overlooked as a possible association in those with DB.¹³⁷

Acute shortness of breath is one of several symptoms for which flight diversion is advised.¹³⁸ Diversions are costly, typically

ranging from £10 000–£80 000 depending on aircraft size and diversion destination.¹³⁹ Dyspnoea caused by DB or hyperventilation is unlikely to have serious clinical consequences; but it must be distinguished from dyspnoea attributable to life-threatening acute medical conditions such as acute coronary syndrome or PE.^{1 140}

Data from the last two decades suggest that 65% of in-flight medical emergencies were due to exacerbations of pre-existing conditions and that respiratory problems were most common; half were due to asthma or 'asthma-like' presentations.^{141–143}

Air travel can be stressful. Physiological or psychological stress may precipitate acute breathlessness in patients with respiratory disease.¹⁴⁴ Acute hyperventilation can be a response to stress independent of lung pathology, usually in those with known panic and anxiety disorders.¹⁴⁵

Hyperventilation can cause bronchoconstriction resulting in 'asthma-like' symptoms¹⁴⁶ which are unresponsive to standard asthma medication.^{147 148} A perception that the usual 'rescue' medication is 'not working' may worsen an individual's breathing pattern, causing concern to them, other passengers and air crew. Similar situations can arise with ILO or VCD, and onset of symptoms is often sudden.¹⁴⁹

Where DB is linked to respiratory conditions, particularly asthma, national and international guidelines endorse breathing exercise programmes provided by a specialist respiratory physiotherapist as an adjuvant to pharmacological treatment. Patients should be advised to use breathing techniques in situations where breathlessness may become problematic.^{75 150} ILO and VCD, which can present with acute respiratory distress and stridor, may be treated with breathing exercises taught by a respiratory physiotherapist or a speech therapist with specialist expertise in paradoxical vocal cord movement.¹⁵¹

Paper bag rebreathing is no longer recommended, because inspired oxygen concentration decreases sufficiently to endanger hypoxic patients. There are data reinforcing that significant harm to patients can result from acute myocardial infarction, pneumothorax and PE being misdiagnosed as hyperventilation.^{152 153}

Clinical practice points

- ▶ Patients with DB, ILO and/or VCD should be referred to a Respiratory Physiotherapy Specialist for advice on symptom management before travel.
- ▶ Those with anxiety disorders should be reviewed before travel; compliance with medication assessed; and use of short acting anxiolytics encouraged.
- ▶ Other life-threatening conditions presenting with dyspnoea should be excluded on board as far as possible.
- ▶ Supplemental oxygen should be given on board if the cause of breathlessness is unclear.
- ▶ Rebreathing via a paper bag is not recommended.

Appendix A Logistics of air travel with equipment

Oxygen

Passengers requiring oxygen and travelling overseas will usually need to lease a POC privately, since UK companies do not generally allow equipment provided through the NHS to be taken out of the country. Furthermore, most airlines have moved away from supplying routine medical oxygen.

Where battery powered mechanical devices are required in-flight, including a POC, sufficient batteries should be carried for 1.5 times the anticipated duration of the journey to cope with delays or diversions. For example, a patient using a POC on a 4-hour flight should have 6 hours of battery life. Any spare

batteries must be correctly packaged and should be carried in cabin baggage. The airline must be notified in advance of these plans, or airline staff can refuse to allow the equipment to be taken on board.

Pulse-dose oxygen may not be suitable for patients with a fast and shallow respiratory pattern, or during sleep.^{154 155} Pulse-dose settings do not equate to the equivalent continuous flow rates,⁷⁴ and not every POC functions well at altitude.¹⁵⁶ In contrast, pulse-dose oxygen functions reliably when provided by a cylinder and conserving device.¹⁵⁶ One author found significantly lower PaO₂ values when using a POC, compared with compressed oxygen with a conserving device. Acceptable in-flight values are achievable with POCs, but the dose may need to be increased.⁵⁶

Pulse-dose delivery systems can complicate determination of the flow delivered; and may not be well tolerated. The effects of mouth-breathing, speech, snoring and/or sleeping should be considered. HFNO cannot be delivered on board commercial aircraft.

Pulse-dose oxygen has not been studied in infants and children; and should not be used unless they have been shown to trigger the device's inspiratory flow.

Currently available POCs that do supply continuous flow oxygen cannot provide flow rates above 3 L/min. Passengers must refer to POC documentation to check that the equipment meets their requirements before they lease it for air travel.

For all these reasons, assessments would ideally take place using the same equipment as that which will be used on board the aircraft. This is only likely to be possible when the patient has leased or purchased a POC for their own long term, private use.

Continuous positive airway pressure

Few airlines, if any, allow any medical device to be powered via the aircraft power supply. An appropriate battery must, therefore, be used. The device and battery specifications must be approved for use by the airline before travel. Battery performance should be checked by the user beforehand, so there is an understanding of operating times on their usual settings.

Further consideration needs to be given to CPAP use during flight and at high altitude destinations, as it requires a machine that will perform adequately at low ambient pressure. The 2011 BTS guidance¹ reported that a fixed-pressure CPAP machine without pressure compensation, set to deliver a pressure of 12 cm H₂O at sea level, may deliver only 9 cm H₂O at 8000 ft. The machine may therefore require adjustment to ensure a safe level of treatment throughout the flight. If continuous flow oxygen cannot be provided by the airline or by POC, oxygen and CPAP cannot be used simultaneously. The availability of distilled water for humidifiers may be restricted.

Non-invasive ventilation

For patients established on NIV, further planning and advice are required to support the use of NIV during flight. If continuous flow oxygen cannot be provided by the airline or by POC, oxygen and NIV cannot be used simultaneously. A decision around whether NIV or supplementary oxygen is of greatest physiological importance to the patient is then required on an individual basis. Previous travel history, current clinical condition and the presence or absence of overnight travel should also be considered. The level of clinical and personal dependency must be considered in the context of requirements for trained supervision and assistance by the caregiver.

Appendix B Quick reference guide for respiratory physiologists

Most patients with respiratory conditions are able to fly safely without any additional support. The following guide provides specific information for respiratory physiologists regarding patients who do need further investigation before embarking on air travel. See figure 3.

HCT methods

The HCT uses an inspired gas mixture containing 15% oxygen, which gives an approximate similar PO₂ to breathing air at the maximum allowable cabin pressure altitude (2438 m or 8000ft).^{53 54} HCT is usually performed in a specialist respiratory physiology unit. The provision of a 15% oxygen gas mixture can be achieved as follows:

- ▶ A premixed cylinder containing a 15% oxygen gas mixture can be obtained from medical gas providers, or Douglas bags can be mixed with air and nitrogen to reduce the percentage of inspired oxygen to 15%, both to supply a tight-fitting face mask in a closed circuit.¹
- ▶ Pure nitrogen can be introduced into a sealed chamber such as a body plethysmograph for paediatric or mask-intolerant patients, removing the need for a face mask.¹⁷ Paediatric patients can be sat in a body plethysmograph on an adult's lap throughout;¹ the adult should also undergo SpO₂ monitoring to avoid excessive hypoxaemia. A body box is generally used for children, although some paediatric laboratories use masks
- ▶ A 40% Venturi oxygen mask can be used with pure nitrogen as the driving gas, giving a resultant gas mixture containing approximately 15% oxygen.^{11 58}
- ▶ A hypoxic gas generator, like an oxygen concentrator, can be used to provide a continuous supply of variable hypoxic gas mixtures to supply a mask or closed chamber. This can be the most cost-effective method for centres with a high demand for HCT.¹²

The patient usually breathes the hypoxic gas mixture for 20 min, or until SpO₂ reaches 85%. Although this is shorter than the briefest commercial flight, oxygenation equilibrium is usually reached within this time.^{134 157} The patient is advised to have in-flight oxygen if PaO₂ falls below 6.6 kPa (<50 mm Hg) or SpO₂ remains <85%^{1 17} (see page 11).

HCT with oxygen

If PaO₂ or SpO₂ values meet the criteria, in-flight oxygen is recommended.¹ The flow rate required can be assessed as part of the HCT.¹⁷ Previous BTS recommendations advised in-flight oxygen to be supplied at two or 4 L/min via nasal cannulae, which were for many years the only fixed flow rates routinely available on commercial aircraft. As airline-supplied in-flight oxygen becomes less common and greater numbers of patients travel with flight-approved POCs delivering a wide range of continuous and intermittent flow rates, these figures are less critical. The HCT should ideally be performed with the modality that is intended for use in-flight.

Most airlines have moved away from supplying routine medical oxygen. In-flight oxygen is thus now likely to be supplied by an FAA approved POC, leased by the patient. These are mostly pulse-dose delivery. It is, therefore, advisable to conduct a titrated HCT with pulsed dose oxygen to maintain PaO₂ at ≥6.6 kPa or SpO₂ ≥85%, using setting 2 as the starting point. This approximates to the 2 L/min originally stated. If pulse-dose oxygen at higher settings is insufficient to maintain PaO₂ at ≥6.6 kPa or

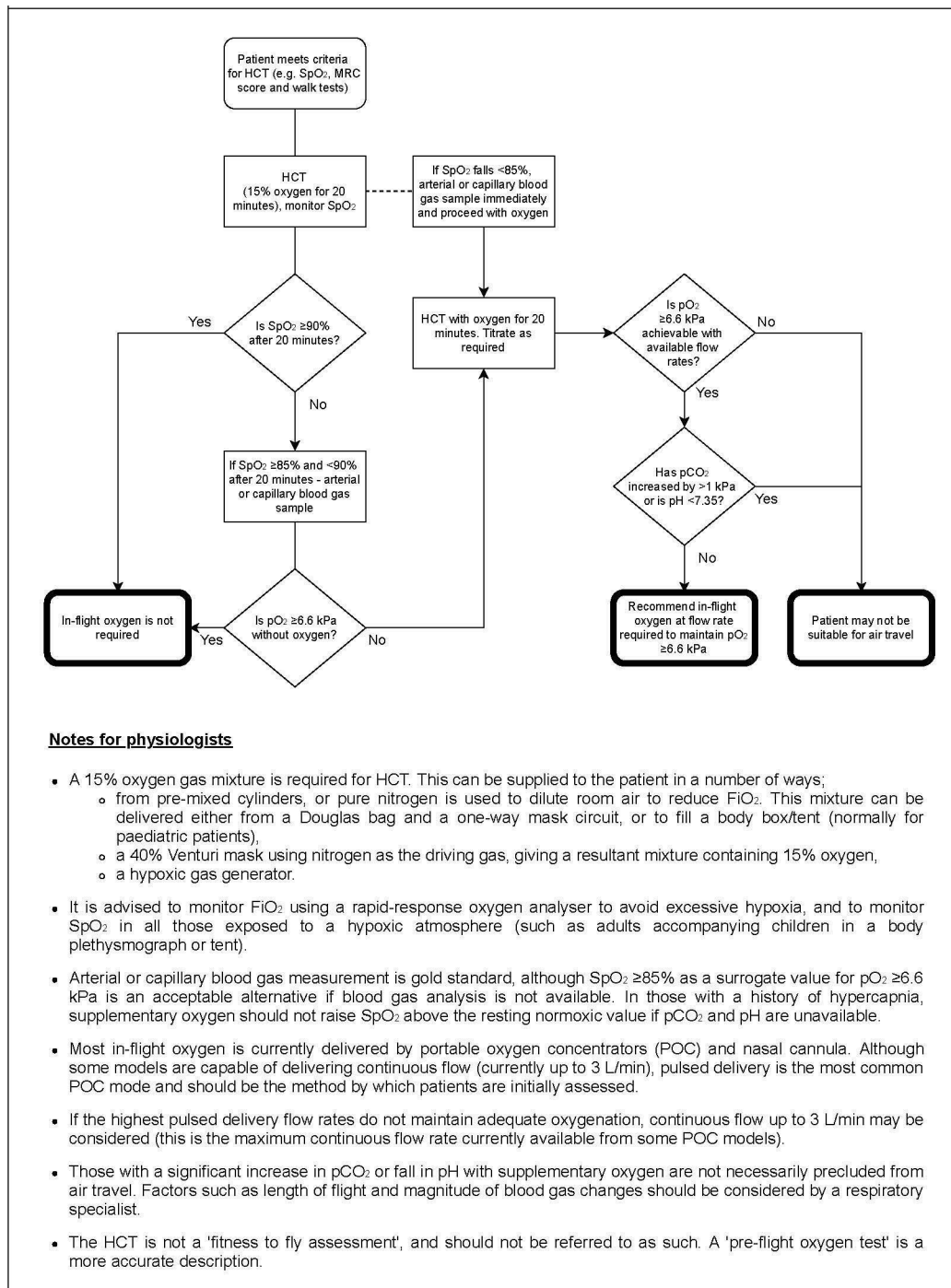


Figure 3 HCT for physiologists.

$\text{SpO}_2 \geq 85\%$, then continuous oxygen should be considered. It should be noted that POC models supplying continuous flow are limited, and they do not currently supply $>3\text{ L/min}$.

Pulse-dose delivery is not suitable for young children, for use during sleep^{154 155} or for certain adults. Not all POCs function as expected under conditions of simulated altitude¹⁵⁶ and pulse-dose settings may not equate to equivalent continuous flow rates⁷⁴ (see Appendix A).

Patients with hypercapnia

Previous BTS advice was to err on the side of recommending oxygen if in doubt,¹ and other authors have recommended doubling oxygen flow rates for patients with a pre-existing

oxygen requirement.^{1 29} However, there is a potential risk of developing hypercapnia and respiratory acidosis from oxygen during HCT in patients with type 2 respiratory failure.¹⁸ Patients with a history of hypercapnia should ideally undergo HCT with blood gas sampling. In these cases, the minimum amount of oxygen should be delivered to maintain $\text{PaO}_2 \geq 6.6\text{ kPa}$ while monitoring PaCO_2 and pH. If blood gas sampling is not available then care should be taken not to raise SpO_2 above the resting level with supplementary oxygen in this group of patients.¹⁷ In some cases it may be unsafe to undertake air travel even if good oxygenation can be achieved, if adverse PCO_2 and pH changes are evident.¹⁸

An incidental finding of an elevated COHb during HCT represents an important opportunity to take a smoking history and offer smoking cessation referral as appropriate.

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