Air travel and chronic lung diseases

9-11-2018

Outline

- Flight environment and effects of high altitude
- Clinical pre-flight assessment
- Respiratory disorders with potential complications for air travels
- Summary of guidelines

Flight environment

- Most air travel troposphere (sea level → 36000 ft/60000ft)
- Commercial airlines – 36000 ft
- Temperature decline is linear Pressure decline is exponential
- 760mm Hg at sea level Half at 18000 and further halves with every 18000ft

Flight environment

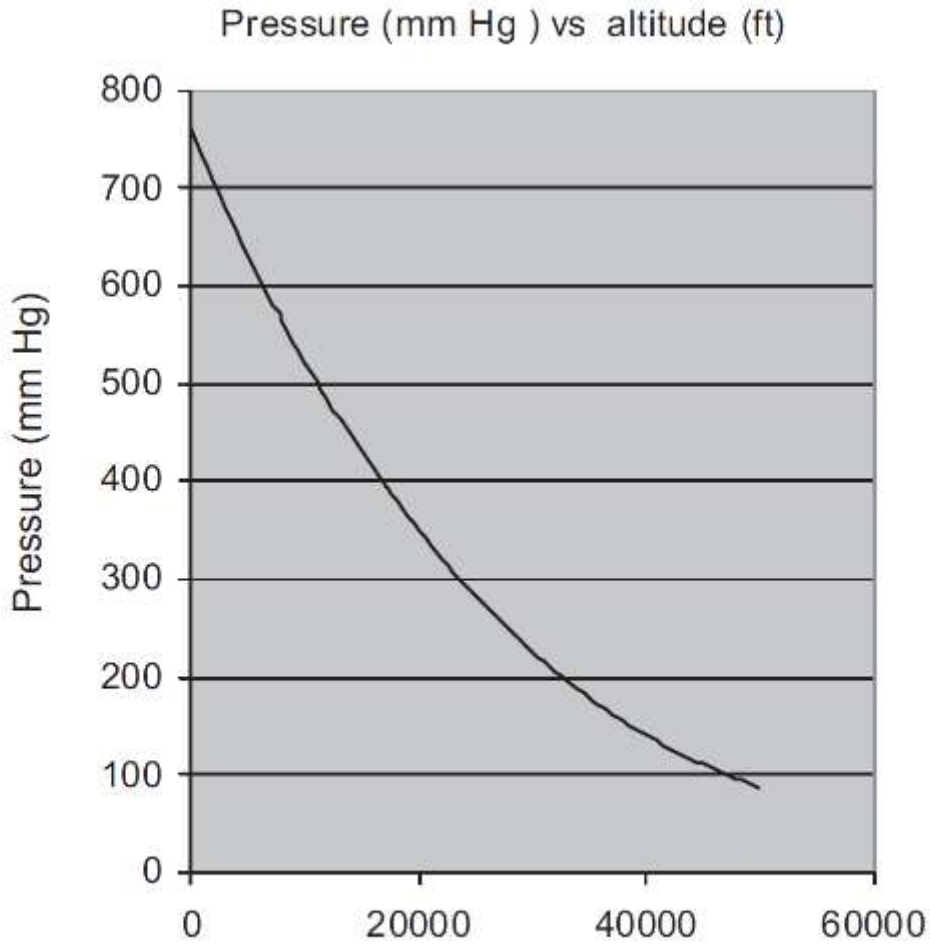


Figure AI Relationship between atmospheric pressure (mm Hg) and altitude (ft).

Flight environment

- Chemical composition is constant
  - N2 78%
  - O2 21%
- Composition of air is constant at any altitude but partial pressure of each component reduces with altitude
- Partial pressure of O2 reduces with ascent
- Partial pressure of O2 148mm Hg → 108mm Hg (sea level to 8000ft)
- Equates to breathing FiO2 of 15% at sea level

Flight environment

- Normal individuals
  - Results in fall in PaO2 53-64 mm Hg
  - Hypoxia →peripheral chemoreceptor stimulation → Hyperventilation and increase in CO → PAO2 increase → PaO2 increase , increase in blood flow and O2 delivery
  - Asymptomatic

Flight environment

- Aircraft cabins
  - Pressurised
  - Aircraft cabins are designed with pressure differentials which represent the compromise between the physiological ideal and the optimal technological design
  - Effective altitude is much lower than the real altitude the plane is at
  - But cannot be pressurised to match sea levels
  - Aircraft cabin pressures 8000ft when flying at 38000ft
  - Federal aviation regulations cabin altitude <8000ft except in emergency
  - Based on oxyhaemoglobin dissociation curve which shows that up to that level the SpO2 normally remains above 90% in the average healthy individual

Flight environment

- Aircraft cabins
  - Outside air drawn into cabin from engine
  - Air is cooled - compressed
  - Cabin pressure is determined by rate of air intake and of air output
  - 50% cabin air expelled, 20-30 complete exchanges per hour
  - Mean cabin altitude in a study of 204 commercial flights → 6214ft
  - Boeing 787 Dreamliner → max 6000ft

Flight environment

- Aircraft cabins
  - Increase incidence of subject discomfort 7000-8000ft for 3-8 hours
  - Cabin decompression – Emergency O2 supply can protect for 15min
  - Pilots expected to descend to safer altitudes in that time
  - Patients with lung disease/impaired respiratory function – susceptible to effects of ascent to normal cabin altitudes

Flight environment

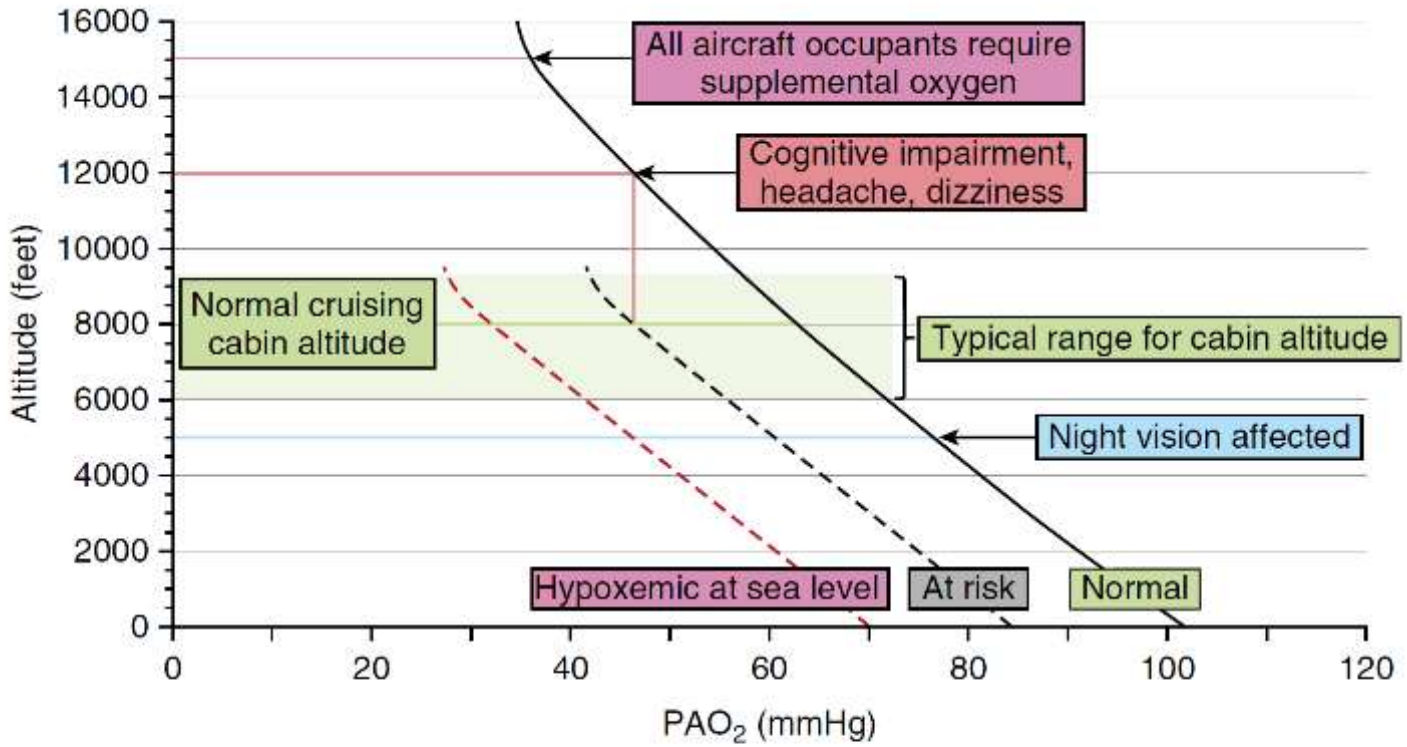


Figure 1. Relationship between cabin altitude and calculated alveolar oxygen tension ($P_{A_{O_2}}$) in a person with normal $P_{A_{O_2}}$ at sea level, an individual "at risk," with decreased $P_{A_{O_2}}$ that is within normal limits, and an individual with a $P_{A_{O_2}}$ at sea level that would be associated with significant hypoxemia. Also indicated are altitude thresholds whereby pilot, air crew, and healthy passengers are required to use supplemental oxygen

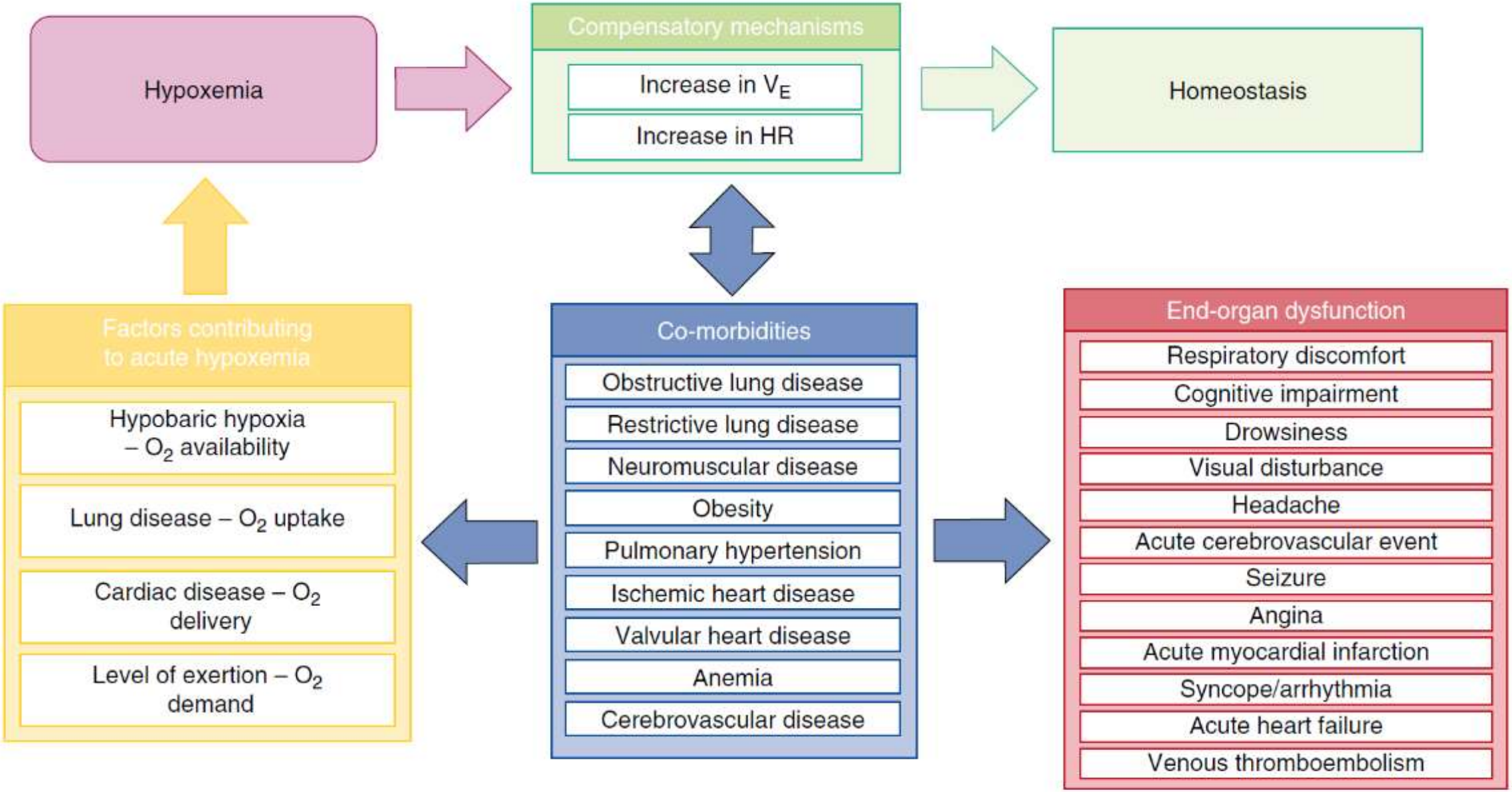


Figure 2. Factors contributing to hypoxemia at altitude, compensatory mechanisms, the potential influence of comorbid illness, and possible end-organ complications of hypoxemia. HR = heart rate; V_E ($\dot{V}E$) = minute ventilation.

Table 1. Symptoms of acute hypoxemia and Federal Aviation Administration altitude thresholds for use of supplemental oxygen in crew and passengers

Cabin Altitude	$P_{I_{O_2}}$: mm Hg (% of Sea-Level Values)	Symptoms	FAA Recommendations on Use of Oxygen at Altitude
Sea level	150 (100)	• None	• Supplemental oxygen not required
5,000 ft	124 (83)	• Night vision may become affected	• Pilots to use supplemental oxygen at night
8,000 ft	110 (74)	• Night vision affected	• Pilots to use supplemental oxygen during day at cabin altitudes above 10,000 ft
12,000–15,000 ft	83–94 (56–63)	• Impairment of judgment • Memory impairment • Decreased alertness • Headache, dizziness • Euphoria	• Cabin crew to be provided with supplemental oxygen within 30 min of exposure to altitudes of 12,500–14,000 ft, and immediately above 14,000 ft
Above 15,000 ft	<83 (<56)	• Peripheral visual field defects occur • Unconsciousness can occur	• All occupants of aircraft require supplemental oxygen

Shown are cabin altitude, partial pressure of inspired oxygen ($P_{I_{O_2}}$; mm Hg), and symptoms of hypoxemia together with Federal Aviation Administration (FAA) recommendations on supplemental oxygen for pilots, passengers, and crew.

Statistics

- A medical emergency occurs in 1 out of every 604 flights and per 30000 passengers
- Respiratory illnesses comprise ~12% of all in-flight emergencies
- Respiratory illnesses 3rd most common cause of diversions
- Other emergencies include syncope (37.4%), cardiac symptoms (7.7%), stroke (2%) and cardiac arrest (0.3%)
- 65% are due to a pre-existing medical condition
- Diversions/emergencies – significant financial and legal burden – Hence pre-flight clinical assessment

Ergan B, Akgun M, Pacilli AMG, et al. Should I stay or should I go? COPD and air travel. Eur Respir Rev 2018; 27: 180030

Pre flight assessment – History Examination Spirometry

- History of chronic lung disease and whether preoptimised and details of last exacerbation
- Previous flying history
- Presence of comorbid illness cardiac anemia, neurological illness
- Contraindications to fly
- Pulse oximetry – (less reliable predictor of in flight SpO2)
- Spirometry should be performed on patients with a history of acute or chronic lung disease or with symptoms suggestive of lung disease
- Confirmed with arterial blood gases especially if hypercapnia is suspected
- Tests to predict In-flight hypoxia

Pre flight assessment – Assessing the risk for hypoxia

- Walk tests
- Predicting hypoxemia from equations
- Hypoxic challenge tests

Pre flight assessment

- Walk test
  - Ability to walk 50 m without distress
  - Simple but crude assessment of cardiorespiratory reserve
  - No evidence validating walk test but preferred by commercial airlines
  - Failure to complete or moderate to severe respiratory distress (recorded on VAS) will alert to possible need for in-flight oxygen
  - Not suitable for those with impaired mobility

Ahmedzai et al Thorax 2011;66:i1ei30

Pre flight clinical assessment

- Predicting hypoxemia from equations
  - The equations have been derived almost exclusively from patients with COPD who have had PaO_2 measured in a hypobaric chamber, or before and during exposure to simulated altitude while breathing 15% inspired oxygen from a reservoir bag
  - Tend to overestimate the need for oxygen supplementation during flights

Pre flight assessment

BTS guidelines

APPENDIX 8
Examples of equations for predicting hypoxaemia

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

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

Pre flight assessment

- Normobaric hypoxia challenge test
  - Preferred method to assess for hypoxia in flight
  - Uses decreased fraction of inspired O2 to simulate in hypoxic conditions at altitude
  - The maximum cabin aaltitude of 8000 ft can be simulated at sea level with a gas mixture containing 15% oxygen in nitrogen
  - Delivered through a non rebreathing valve → tight fitting face mask or mouth piece or a plethysmograph/hood or a 40% venturi mask with 100% N2
  - Duration: 20 mins
  - SpO2 monitored throughout and PaO2 monitored prior to and after test

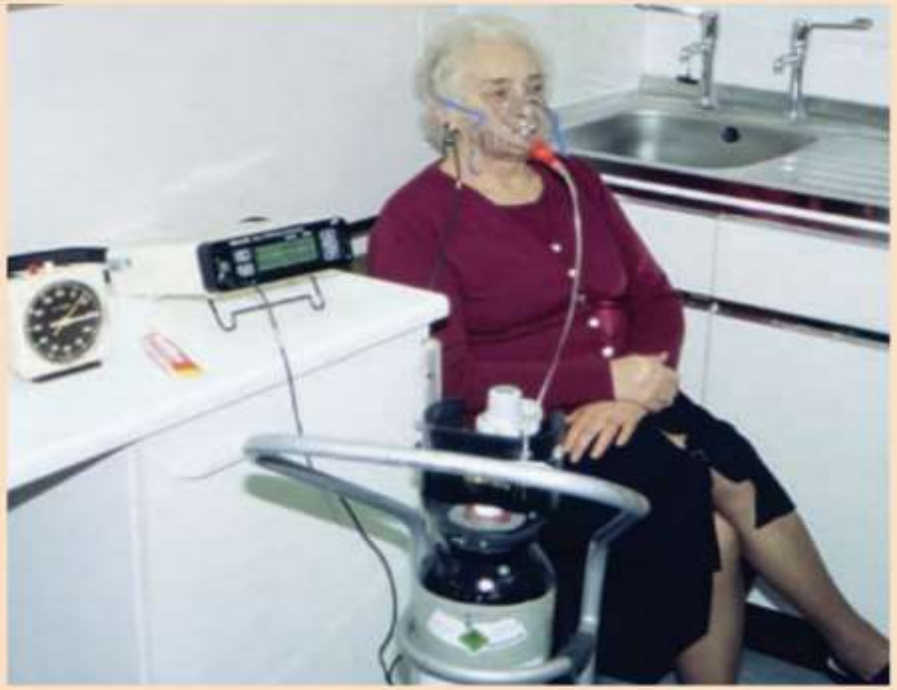
Ahmedzai et al Thorax 2011;66:i1ei30

Normobaric HCT

Hypoxic challenge: a suggested protocol

The protocol described below has been used by the authors for a number of years and appears to be well tolerated by all patients. An interpretation algorithm of the results of hypoxia inhalation test carried out using this protocol can be found in [20].

1. Prepare the patient's earlobe by rubbing with a topical vasodilator cream.
2. Attach a pulse oximeter ear probe to the patient, and record resting S_{a,O_2} and heart rate every 30 seconds for 5 minutes with the patient breathing room air.
3. Fit the patient with nasal cannulae, which are connected to a supply of 100% O_2. The cannulae are used to deliver supplemental O_2 if required.
4. Place a 40% Venturi mask over the patient's face, ensuring a good fit. The Venturi mask is supplied with 100% nitrogen at a flow of 10 litres per minute, which lowers the patient's F_{i,O_2} to 15.1%.
5. Record S_{a,O_2} and heart rate every 30 seconds for 20 minutes.
6. Patients on long-term oxygen therapy can be assessed using the same protocol, but with the patient receiving supplemental oxygen by nasal cannulae at a flow of 2 litres per minute during HIT.



Pre flight assessment

- Normobaric hypoxia challenge test
    - $PaO_2 < 50$mm Hg or $SpO_2 < 85\%$ → In flight supplemental O_2
- Hypobaric hypoxia challenge test
    - Not widely available/only at research facilities

Hypobaric HCT

Hypobaric chamber at the Colarado Center for Altitude Medicine and Physiology. Picture from CNN (www.cnn.com).

in the UK.

Hypobaric chambers have been used for research purposes [16], but they are not common and the current authors are not aware of

Who should have a hypoxia challenge test?

- 97 patients who had HCT over 18 month period – evaluated
- Mean age 52 years
- CF 34% ILD 29% COPD 20%
- Most patients with COPD and 50% ILD patients had positive test
- Pretest PaO2 was the most accurate predictor of a positive test
- All had a walking distance of >65 metres with no correlation between distance and positive results
- No correlation with FEV1
- Indications – disease specific

European Respiratory Journal 2017 50: PA2249

Pre flight assessment

Table 3. Methods for assessment of hypoxia at altitude

Method	Patients Studied	Advantages	Disadvantages
Sea-level Sp_{O_2}	COPD, ILD, CF	Ease of use	Underestimates oxygen requirements
Predictive equations	COPD, ILD, CF	Ease of use	Overestimates oxygen requirements
Normobaric hypoxic testing	COPD, ILD, CF	Widely available Good correlation with in-flight Sp_{O_2}; technically easy to perform	May underestimate Sp_{O_2} on exertion; suboptimal at titrating supplemental oxygen
Hypobaric hypoxic testing	COPD, ILD, CF	Reproduces hypobaric environment More accurate estimation of Sp_{O_2} at altitude; superior at titration of supplemental oxygen	Not widely available Technically more complex to perform

Definition of abbreviations: CF = cystic fibrosis; COPD = chronic obstructive pulmonary disease; ILD = interstitial lung disease; Sp_{O_2} = oxygen saturation as determined by pulse oximetry.
Shown are methods for assessment of hypoxemia at altitude and relative advantages and the disadvantages of each.

Ahmedzai et al Thorax 2011;66:i1ei30

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

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

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

Ahmedzai et al Thorax 2011;66:i1ei30

Air travel in patients with COPD

Risk of flying in COPD

- Moderate and severe COPD have a higher risk of significant hypoxaemia during air travel
- Patients with reduced PaO2 have a further decline in PaO2
- Hypercapnea indicates lower reserves and may experience greater hypoxia when exposed to commercial airline travel
- Hypoxaemia-induced hyperventilation→ hyperinflation→ iPEEP → respiratory fatigue - especially during long-haul flights

Risk of flying in COPD

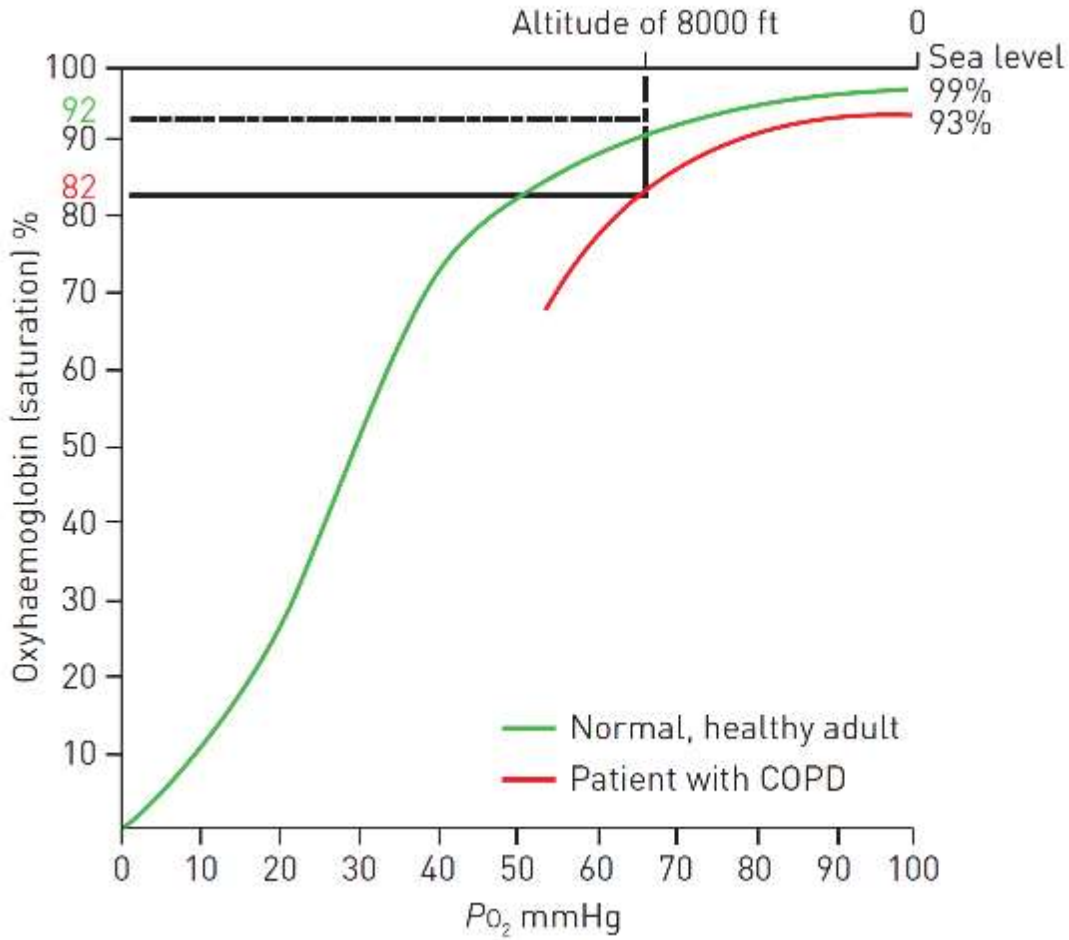


FIGURE 2 Oxyhaemoglobin dissociation curve for healthy individuals and patients with chronic obstructive pulmonary disease (COPD) at high altitude. P_{O_2}: oxygen tension. Reproduced from [26] with permission.

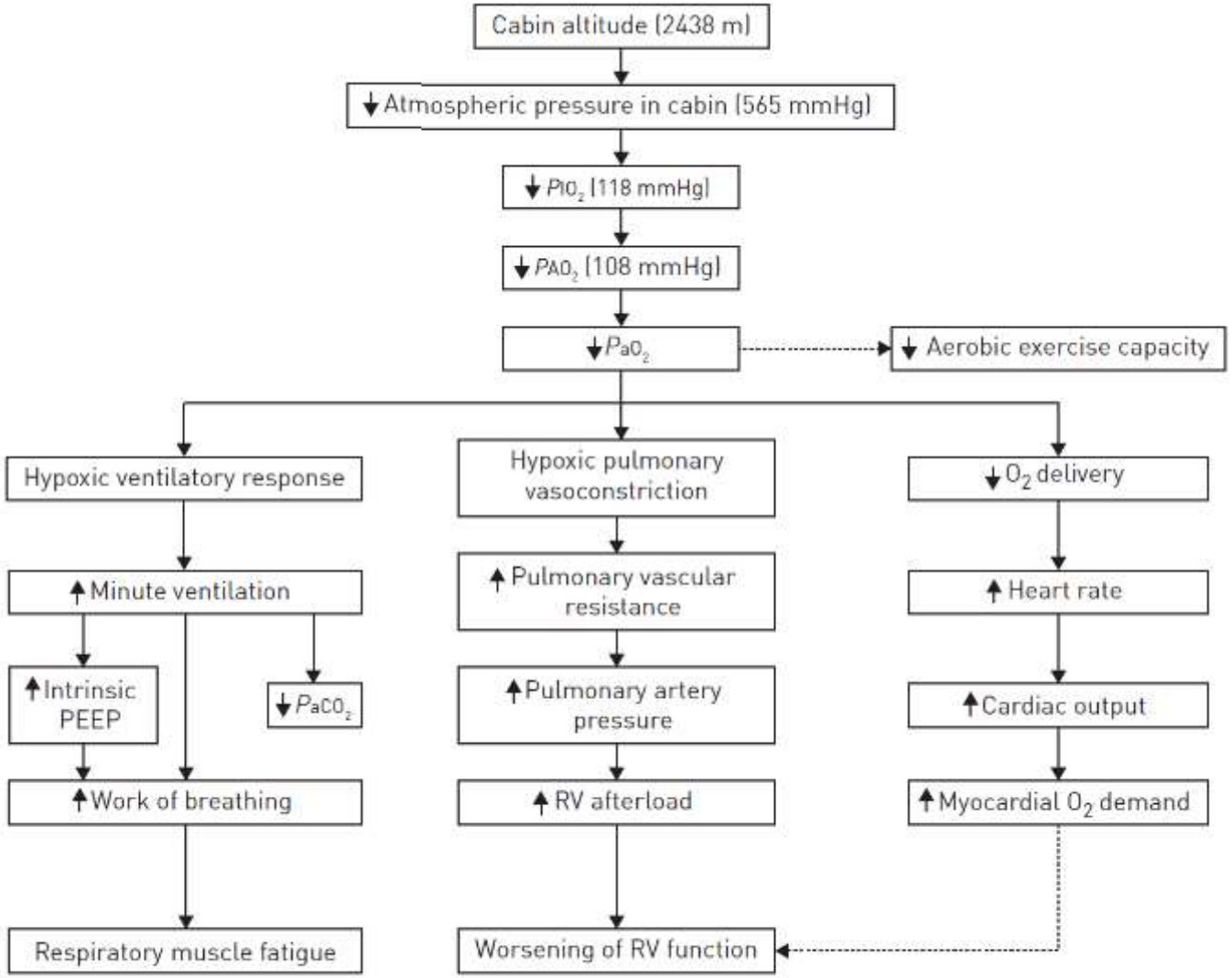


FIGURE 3 Pathophysiological changes in chronic obstructive pulmonary disease during air travel. P_{IO_2}: inspired oxygen tension; P_{AO_2}: alveolar oxygen tension; P_{aO_2}: arterial oxygen tension; P_{aCO_2}: arterial carbon dioxide tension; PEEP: positive end-expiratory pressure; RV: right ventricle.

Ergan B, Akgun M, Pacilli AMG, et al. Should I stay or should I go? COPD and air travel. Eur Respir Rev 2018; 27: 180030

Risk of flying with COPD

- Other problems
  - Sleep sleep may cause relatively significant desaturations in COPD patients who are more vulnerable to hypoxemia
  - Alcohol or other sedatives, including sleeping pills, may exacerbate this by increasing sleepiness and actual sleep time
  - Expansion of gases
    - Volume of gas is inversely proportionate to the pressure
    - 1L of gas expands to 1.4L at 8000 feet (Boyle s law)
    - Gas expansion in closed units like bullae/blebs or in those with prior pneumo→pneumothorax
  - Lower humidity → Increase in airway hyperreactivity

Ergan B, Akgun M, Pacilli AMG, et al. Should I stay or should I go? COPD and air travel. Eur Respir Rev 2018; 27: 180030

Manifestations

- Dyspnoea
- Air hunger hyperventilation
- Light-headedness chest pain
- Tingling in the extremities and palpitations
- Dyspnea → walking down the aisle

Assessment in COPD

- COPD patients with dyspnoea on exertion
- FEV1 <1.5 L or <30% predicted
- Pre-existing requirement of oxygen
- Bullous lung disease
- Comorbid conditions that worsen hypoxia cardiac illness
- Significant symptoms during previous air travel
- Recent exacerbations

Assessment in COPD

- SpO2
  - >95% and no risk factors → may not require O2 supplementation
  - <95% or >95% with risks→ further testing
  - Cut offs arbitrary
  - A study of 100 COPD patients divided into groups according to SpO2 and risk factors before performing HCT
    - Percentage of patients in whom PaO2 <50mm Hg after HCT
      - 30% in the SpO2 >95% group
      - 67% in the SpO2 92– 95% and without additional risk factors
      - 70% in the SpO2 92–95% and additional risk factors
      - 83% in the SpO2 <92% group

Aviat Space Environ Med 2008; 79: 518–524

Assessment in COPD

- PaO_2
  - ABG needed if SpO_2 <95%
  - PaO_2 <70mm Hg → HCT
  - Some studies show correlation of PaO_2 levels with in flight desaturation but others do not

Assessment in COPD

- PaO2

Author [ref.]	Year	Patients	Test/condition used	Results
Gong [33]	1984	22 moderate COPD	HCT	Sea level P_{aO_2} predicted acute resting altitude P_{aO_2}
Dillard [51]	1989	18 severe COPD	Hypobaric chamber	Ground P_{aO_2} correlated with expected altitude P_{aO_2}, combination of FEV1 and ground P_{aO_2} improved prediction of P_{aO_2} at 8000 ft
Schwartz [52]	1984	13 severe COPD	Inflight ABGs at 1650 m and 2250 m	P_{aO_2} measured <2 h before the flight in room air or a 17.2% oxygen mixture correlated with P_{aO_2} at 1650 m. P_{aO_2} measured several weeks before flight did not correlate with any in-flight measurements
Berg [31]	1992	18 severe COPD	Hypobaric chamber	Oxygen supplementation *via* nasal cannula or Venturi mask corrects altitude hypoxaemia
Christensen [30]	2000	15 severe COPD	HCT	Pre-flight P_{aO_2} >70 mmHg, FEV1 or T_{LCO} values do not predict altitude hypoxaemia. Light exercise may provoke hypoxaemia and there was a correlation between aerobic capacity and altitude P_{aO_2}
Robson [53]	2000	20 COPD (15 severe) and 8 other RD	HCT	Altitude P_{aO_2} could not be predicted from either FEV1 or pre-test S_{pO_2}
Seccombe [35]	2004	10 COPD and 15 ILD	HCT with 50-m walk test	Resting sea level P_{aO_2} is poor for predicting the hypoxaemic response in both COPD and ILD groups. Means of P_{aO_2} of both groups fell below recommended levels at both resting and when walking during HCT
Akero [34]	2005	18 COPD	In-flight ABG	Significant desaturations were observed during flight, which were worsened with activity. A pre-flight P_{aO_2} >70 mmHg did not predict in-flight hypoxaemia. Aerobic capacity

Ergan B, Akgun M, Pacilli AMG, et al. Should I stay or should I go? COPD and air travel. Eur Respir Rev 2018; 27: 180030

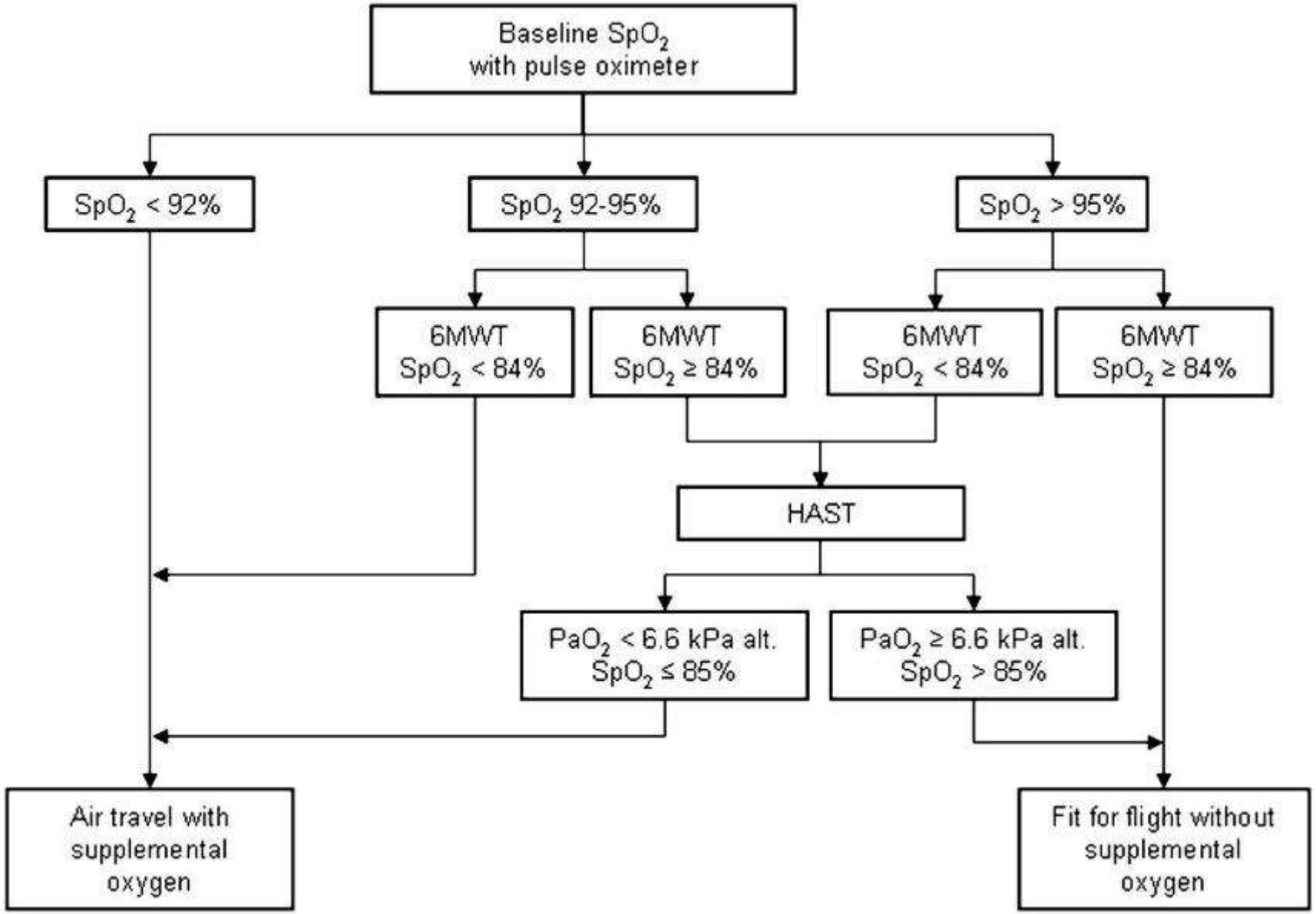
Assessment in COPD

- Walk test
  - 50m walk (10–12 stairs) without any distress are considered to have sufficient cardiopulmonary reserve for flying
  - Resting SPO2 >95% combined with a 6-min walk test SPO2 >84% has a sensitivity of 100% and specificity of 80% for fitness to fly

Assessment in COPD

Author	Year	Patients	Test/Condition	Results
Chetta *et al*	2007	15 COPD 15 ILD	HCT 6MWT	SpO2 in 6MWT can predict O2 desaturation during HCT
Edvardsen *et al*	2012	100 severe COPD	HCT and 6MWT	An algorithm was constructed using a combination of resting and 6MWT SpO2. Resting SpO2 > 95% combined with 6MWT SpO2 >84% had sensitivity of 100% and specificity of 80% for fitness to fly

Edvardsen A, Akero A, Christensen CC, et al. Air travel and chronic obstructive pulmonry disease: a new algorithm for preflight evaluation. Thorax 2012; 67: 964–969



Edvardsen A, Akero A, Christensen CC, et al. Air travel and chronic obstructive pulmonry disease: a new algorithm for preflight evaluation. Thorax 2012; 67: 964–969

Assessment in COPD

- HCT
  - SpO2 in HCT well correlated with in-flight mean SpO2
  - However PaO2in HCT was not associated with the presence of symptoms during air travel
  - PaO2 >50mm Hg and/or SpO2 >85% No in flight O2 warranted
  - Lower values→ repeat with supplemental O2 2L-4L/min

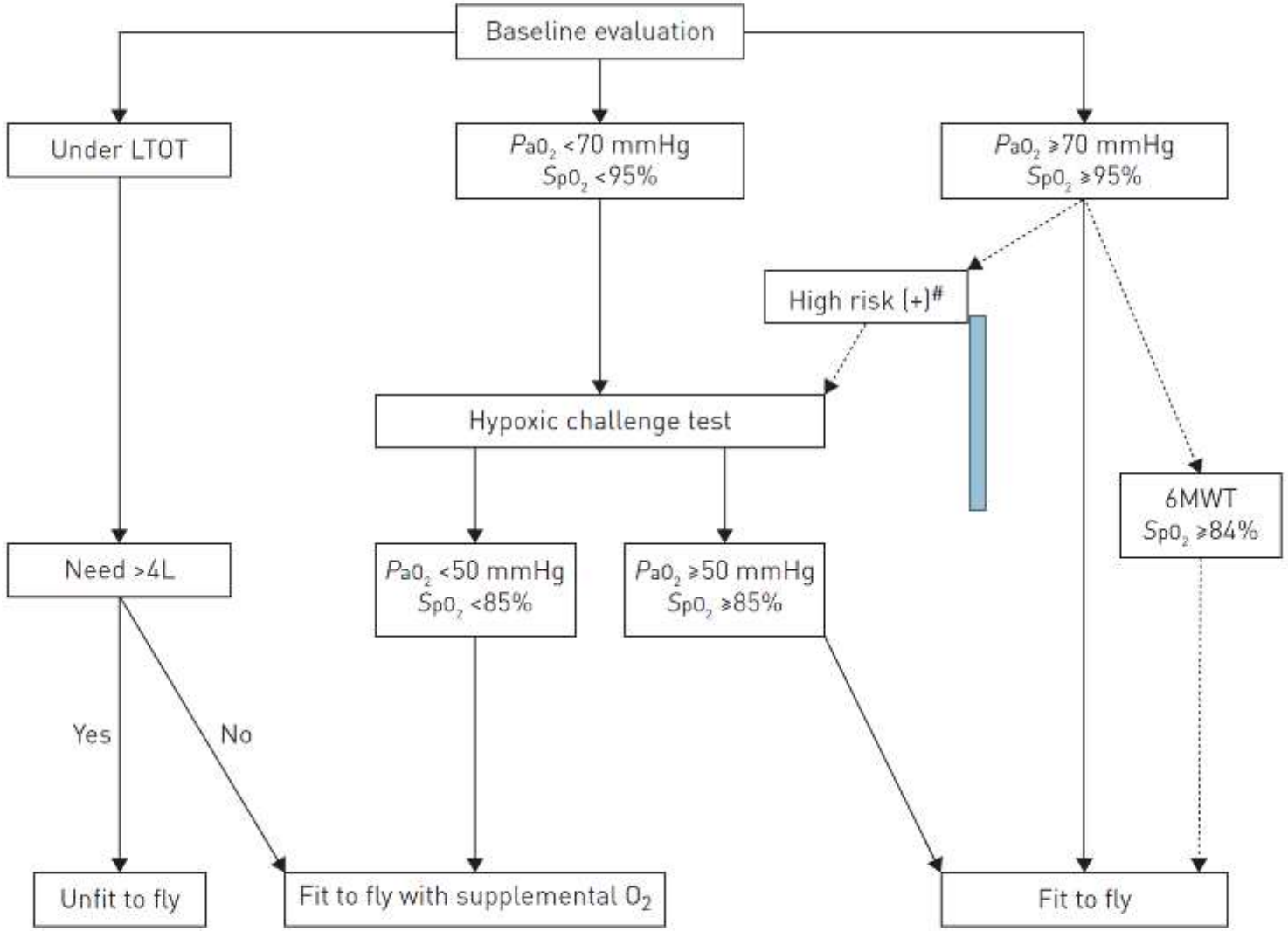


FIGURE 4 Algorithm for the assessment of fitness to fly in chronic obstructive pulmonary disease patients. LTOT: long-term oxygen therapy; $P_{a}O_{2}$: arterial oxygen tension; $S_{p}O_{2}$: arterial oxygen saturation measured by pulse oximetry; 6MWT: 6-min walk test. #: if dyspnoea on exertion, forced expiratory volume in 1 s <1.5 L or <30% predicted, a pre-existing requirement of oxygen/ventilatory support, bullous lung disease, comorbid conditions that may worsen hypoxaemia like cardiac disease and significant symptoms during previous air travel.

Oxygen supplementation

- Oxygen supplementation can be obtained by the airline after a report (MEDIF) indicating oxygen requirement and its prescription by the physician
- Approved compressed gas cylinders are the first choice option for short flights
- Portable battery operated concentrators for long haul flights
- Air India – 72 hour notice for provision/carriage of medical equipment including cylinders/concentrators
- 2-4L/min nasal prongs

Logistics of travel with oxygen

For all patients

- The need for oxygen should be disclosed when the patient books with the airline.
- The airline medical department will issue a MEDIF form (see Appendix 5) or their own medical form. This requires completion by both the patient and the GP or hospital specialist and requests information about the patient's condition and oxygen requirements. The airline's Medical Officer then evaluates the patient's needs.
- The need for oxygen on the ground and while changing flights must be considered.
- The airline should be consulted in advance if the patient wishes to use humidification equipment.
- Airlines do not provide oxygen for use at the airport. Some airports restrict oxygen use in the airport because of the risk of explosion.
- In-flight oxygen flow is usually limited to 2 l/min or 4 l/min.
- Patients cannot use their own cylinder or concentrator but may be able to take these items with them as baggage if empty. They should check with the airline first. Charges may be made for this service, in addition to a charge for in-flight oxygen.
- Patients are advised to check charges with several airlines before reservation as considerable variation exists in fees and services.

For totally oxygen dependent patients

- Special arrangements must be made with the airline and airport authorities. Transport to the aircraft by ambulance is possible, and some airports have a specially designated medical unit.
- Patients should have a supply of all their usual medication, a copy of their medical form, and be accompanied.
- A direct flight is preferable. If connecting flights are unavoidable, separate arrangements must be made for oxygen while on the ground during stopovers. The main oxygen distributors have their own international distribution network and can supply oxygen at intended destinations if active in those areas.
- Patients normally using long term oxygen therapy (LTOT) should ensure that they have LTOT throughout their stay. In case of difficulty, the major UK lung charities may be able to advise.
- Attention should be drawn to the need to make prior arrangements for the return as well as outward journey.

Other measures prior to and on flight

- Optimise bronchodilator therapy
- Recent exacerbation postpone airtravel by 6 weeks
- Ensure all MDIs/DPIs are in cabin baggage
- Direct flights preferred over transits
- Aisle seats and seats close to toilets
- Adequate hydration intermittent leg exercises and avoidance of alcohol
- Risk of exacerbations due to risk of transmission of respiratory viruses from neighbouring passengers

Bronchial Asthma

- Commercial flight environment does not pose problems for those with asthma
- Low cabin humidity→ bronchial mucosal water loss→ bronchospasm
- Hypobaric hypoxia does not pose a risk
- Severe asthma requiring Step 5 therapy warrants HCT

Ahmedzai et al Thorax 2011;66:i1ei30

Bronchial Asthma

- In flight hypoxia in severe asthma
  - Retrospective study 2007-2014 involving patients on Step 5 therapy
  - 37 underwent HCT
  - 21 met criteria for in flight O2 prescription
  - But positive results did not correlate with sea level SpO2 or PaO2
  - Lung function was significantly more obstructed in the positive HCT group

    FEV1 FEV1/FVC and PEFR were significantly better in those with negative test

George et al Aerosp Med Hum Perform. 2016 Jun;87(6):571-574

Bronchial Asthma

- For exacerbations on board
  - Patient’s own bronchodilator inhaler (or airline emergency kit inhaler if available) should be administered (with a spacer where appropriate) and the dose repeated until symptomatic relief is obtained
- FEV1 <30% should consult their respiratory specialist beforehand and consider taking an emergency supply of prednisolone in their hand luggage as well as supplies of their usual medications

Ahmedzai et al Thorax 2011;66:i1ei30

Malignancy

- Challenges
  - Thoracic malignancies
    - Impaired pulmonary function and reserve→COPD
    - Muscle weakness/paralysis
    - Pleural disease and effusion
    - Thoracic cage fixation
    - Hemoptysis
    - Cerebral mets
  - Biochemical abnormalities cachexia muscle deconditioning
  - Neutropenia, VTE risk carrying opioid analgesics
  - Lack of literature – hence most protocols are based on expert opinions

Malignancy

- Treat reversible causes – anemia (Hb >8.5g/dL), airflow obstruction, correct dyselectrolemia
- SVC syndrome Lymphangitis air travel only if necessary– O2 supplementation on board
- Supportive care – cough suppressants, analgesics
- Physician prescription - doctor’s letter required for patients taking controlled drugs giving patient details return dates of travel countries being visited and drugs being carried including doses and total amounts
- Airlines do not allow patients to fly within 24 h of a seizure
- Patients with major hemoptysis should not fly

Pulmonary Hypertension

- Air travel can be safe and well tolerated in patients with clinically stable pulmonary hypertension

Population	Design	Outcomes
Patients of pulmonary hypertension from a German cohort (n = 720)	Anonymous questionnaire based study of those who had undertaken air travel following diagnosis of PHTN	430 returned questionnaires 179 had undertaken air travel NYHA I 2 NYHA II 77 NYHA III 74 NYHA IV 8 Adverse effects 11% (mild/mod) Dyspnea/ peripheral edema NYHA Class IV status more among those who never travelled 4 with adverse effects required supplemental O2

Large proportion of patients with PH travel by air despite the additional risk, and air travel can be safe and well tolerated in these patients in WHO functional class II and III in a stable clinical condition

Pulm Circ. 2011 Apr-Jun; 1(2): 239–243

Pulmonary Hypertension

- Effects of Commercial Air Travel on Patients With Pulmonary Hypertension

Population	Design	Outcomes
Patients with PHTN (WHO group I or IV) Exclusion criteria resting Spo_2 by pulse oximetry < 90% on room air or on oxygen as prescribed, resting HR > 110, inability to walk continuously for 6 min, or any history of a medical emergency occurring during air travel	Prospective observational study during which cabin pressure, oxygen saturation (Spo_2), heart rate, and symptoms were documented serially at multiple predefined time points throughout commercial flights	Median flight duration 3.6h Cabin pressure 6,456 ± 1,218 ft Median change in Spo_2 - 4.9% 26%[95% CI, 12%-38%] desaturation 38% reported symptoms Desaturation associated with cabin pressures > 6000ft, ambulation, and flight duration

Hypoxemia one in four people studied
Hypoxemia associated with lower cabin pressures, ambulation during flight, and longer flight duration
Patients with PH who will be traveling on flights of longer duration or who have a history of oxygen use including nocturnal use should be evaluated for supplemental in-flight oxygen

Pulmonary Hypertension

- HCT → Hypoxia at sea level and pulmonary vascular disease
- Patients with pulmonary hypertension and NYHA Class I & II symptoms→ No O2 supplementation
- Patients with pulmonary hypertension NYHA III and IV → In-flight O2
- ACC/AHA recommends In flight SpO2 SpO2 <92%

Ahmedzai et al Thorax 2011;66:i1ei30

Air borne infections

- Cabin air is recirculated
- Air exchange rates on commercial airliners range from 20-30 changes per hour (more than any average commercial building)
- Cabin air is routed through filters designed to extract droplet (1-3 micrometres) and particulate matter (HEPA)
- Laminar air flow - air is introduced from the ceiling and removed from the floor by passengers' feet
- Humidity kept low to prevent condensation of droplets
- Microbiological composition of cabin air is less than that of air in any city

Ahmedzai et al Thorax 2011;66:i1ei30

Air borne infections

- Tuberculosis
  - No reported cases of clinical active TB transmission during air travel
  - TST positivity in contacts have been reported from known TB cases identified
  - Most contacts have alternate risks for being TST positive apart from exposure to case during air travel
  - Evidence thus suggests that the risk of TB transmission during air travel is low and no higher than in any other confined space
  - Risks for transmission
    - Smear positive cavitating laryngeal flight >8h and proximity to case (within 2 rows)

Air borne infections

- Tuberculosis
  - Patients with infectious tuberculosis (TB) must not travel by public air transportation
  - Patient with infective tb must not travel by air on any commercial flight of any duration until they are sputum smear-negative on at least two occasions
  - Patients with MDR/XDR must not travel by any commercial flight under any circumstances until they are proven to be non-infectious with two consecutive negative sputum culture results

World Health Organization. Tuberculosis and Air Travel: Guidelines for Prevention and Control. 3rd edn. WHO/HTM/TB/2008.399. http://www.who.int/tb/features_archive/aviation_guidelines/en/.

Cystic fibrosis and Non-CF Bronchiectasis

- Patients with CF become hypoxemic at high altitude but are rarely symptomatic
- Those with a low FEV1 (<50%) appear to be at increased risk of hypoxemia
- HCT recommended if FEV1 < 50% and SpO2 < 90% in those not able to perform spirometry

Ahmedzai et al Thorax 2011;66:i1ei30

ILDs

- Evaluation and indications similar to COPD
- Baseline PaO2 and SPO2 do not correlate with altitudinal hypoxia
- HCT warranted for all symptomatic patients, moderate/severe lowering of FEV1 presence of comorbid illnesses
- Hypoxia on HCT warrants in flight O2 supplementation

Obstructive sleep apnea syndrome

- Patients with OSA
  - Snoring – disturb fellow passengers
  - Jet lag worsens with OSAS
  - Avoid alcohol and sedatives before and during flight
  - CPAP recommended while sleeping on flight
  - Challenges for CPAP on board
    - No power supply or compatible adaptors
    - Batteries heavy and limited duration of functioning
    - CPAP use in flight and at high altitude destinations requires a machine that will perform adequately at low ambient pressure – machines with pressure sensors or with pressure compensation

Pneumothorax

- Principle

Boyle' s law illustrated for gas saturated with water vapour

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

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

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

$$(760–47) / (565–47) = 713/518 = 1.38$$

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

Pneumothorax

- Closed pneumothorax – contraindication for air travel
- Air travel 7 days after complete resolution after pneumothorax as demonstrated by CXR
- Traumatic pneumothorax – air travel 2 weeks after complete radiological resolution
- Thoracotomy guided pleurodesis no risk of recurrence
- VATS guided slight increase in risk compared to thoracotomy
- Patients having other forms of attempted pleurodesis and those not undergoing attempted pleurodesis after a previous pneumothorax are unlikely to have further episodes precipitated by flight
- The risk of recurrence is higher in those with coexisting lung disease and does not decline significantly for at least 1 year

Pneumothorax

- Recurrence rates
  - Thoracotomy 1%
  - VATS 3%
  - Medical pleurodesis 5%-9%
- Most recurrences in 1st year 54.2% and 70% in first 2 years
- Small or loculated pneumothoraces
  - Some patients with a closed chronic pneumothorax can fly without adverse consequences
  - Clearance only after extensive evaluation
- LAM – UK+USA LAM registry 10 cases of pneumothorax among 276 patients of LAM who travelled by air
  - Risk of a pneumothorax in flight 2.2% and per woman with LAM 4% and hence presence of LAM should not preclude air travel

Pneumothorax

- Thoracic surgery
  - Almost universal after thoracic surgery
  - CXR required after ICD removal to ensure lung is fully expanded
  - Prudent to wait for 7 days after full expansion and removal of ICD

Pulmonary thromboembolism

- RISK
  - Low
  - Moderate
  - High

Moderate	High
• Family history of VTE • Past history of provoked VTE • Thrombophilia • Obesity (BMI >30 kg/m2) • Height >1.90 m or <1.60 m • Significant medical illness within previous 6 weeks cardiac disease • Immobility • Pregnancy or oestrogen therapy (Hormone replacement and OCP) • Postnatal patients within 2 weeks of delivery	• Past history of idiopathic VTE • Within 6 weeks of major surgery or trauma • Active malignancy

Pulmonary thromboembolism

- Low risk
  - Passengers avoid excess alcohol and caffeine-containing drinks
  - Remain mobile and/or exercise their legs during the flight
- Moderate risk
  - Elastic compression stockings
  - Avoid sedatives
- High risk
  - Prior VTE should avoid travel for 4 weeks or
  - Until proximal deep vein thrombosis has been treated and symptoms resolved with no evidence of pre- or post exercise desaturation
  - Pre-flight LMWH or formal anticoagulation to maintain INR 2-3

Pulmonary thromboembolism

- Data (cohort and case control studies) suggest an overall doubling of risk of VTE after long-haul air travel (>4 h)
- Risk increases with duration 4 fold increase with flights >8h
- Absolute risk of developing asymptomatic VTE ranges from 0 to 10%
- Absolute risk of symptomatic VTE 1 in 4600, rising to 1 in 1200 for journeys >16 h
- Flight-specific factors such as hypobaric hypoxia and/or type of seating may be important in susceptible individuals

World Health Organization. The WRIGHT Project: World Health Organization Research into Global Hazards of Travel. Geneva, Switzerland: WHO Press, 2007

Pulmonary thromboembolism

- Risk of VTE was increased two fold by travel (flight and nonflight) for >4 h
- Height >1.90 m increased the risk when travelling on land by a factor of 4.7, factor V Leiden mutation by 8.1 and OCP useby >20 (risks greater with air travel)
- BMI >30 kg/m2 was associated with increased risk when travelling by land
- Height <1.60 m was associated with increased risk during air travel but not by land

Doggen CJ, van Houwelingen HC, et al. Travel-related venous thrombosis: results from a large population-based case control study (MEGA study). PLoS Med 2006;3:e307

Pulmonary thromboembolism

- The use of aspirin for preventing air travel-associated VTE is not recommended as present evidence does not show any benefit of antiplatelet use
- Pneumatic compression devices appear to be no more effective than leg exercises so may only be relevant in patients who are sedated or immobile

J Korean Med Sci. 2011 Dec; 26(12): 1625–1629

Summary of the BTS guidelines 2011

Table 2. Summary of British Thoracic Society 2011 guidelines with disease-specific recommendations and SIGN grading of evidence

Disease	Considerations	Recommendation	SIGN Grading
Asthma and COPD	• Acute exacerbation during flight	• Give patient's own bronchodilator	D
	• Severe asthma or COPD with $FEV_1 < 30\%$ predicted	• Consult specialist beforehand	D
		• Bring supply of prednisone	D
Bronchiectasis	• General	• Nebulized antibiotics or bronchodilators not required	D
Interstitial lung disease	• General	• Careful assessment of patients recommended	D
		• Consider oxygen supplementation if high-altitude destination	D
		• Bring supply of antibiotics ± prednisone	D
Cystic fibrosis	• General	• HCT recommended if $FEV_1 < 50\%$ predicted	C
		• If $Sp_{O_2} < 90\%$ during HCT, supplemental oxygen is advised	C
Obstructive sleep apnea	• General	• Avoid alcohol and sedatives	D
	• CPAP device	• Use dry-cell batteries in-flight	D
		• CPAP device should be capable of operating at altitude	D
		• Verify that device is operable at altitude and with power supply at destination	D
Pulmonary hypertension/ heart failure	• NYHA class I–III without PH	• May fly without oxygen	D
	• NYHA class I–II with PH	• May fly without oxygen	D
	• NYHA class III–IV with PH	• Should receive in-flight oxygen	D
	• NYHA class IV and severe PH	• Should avoid flying	D
Neuromuscular disease and kyphoscoliosis	• General	• All patients should undergo hypoxic challenge testing	C
Cardiac disease	• Coronary artery disease	• May fly 2 d after PCI	C
		• Low-risk patients after NSTEMI may fly after 3 d	C
		• Those with NSTEMI should undergo PCI before planning air travel	C
	• After coronary artery bypass grafting	• May fly 14 d after CABG once chest radiograph has excluded pneumothorax	C
	• Angina CCS class III symptoms	• Patients with stable CCS class III angina are not expected to develop symptoms	C
	• Angina CCS class IV symptoms	• Patients with CCS class IV symptoms should be discouraged from flying	C
	• Cyanotic congenital heart disease	• At physician's discretion to advise HCT and/or use supplemental oxygen	D
		• NYHA functional class IV should not travel, or should receive in-flight oxygen at 2 L/min	D
	• Unstable arrhythmia	• Should not fly	C
	• Valvular disease	• If hypoxemic at sea level, and coexisting lung or pulmonary vascular disease, consider HCT	D

Definition of abbreviations: CABG = coronary artery bypass graft; CCS = Canadian Cardiovascular Society; COPD = chronic obstructive pulmonary disease; CPAP = continuous positive airway pressure; HCT = hypoxic challenge test; NSTEMI = non–ST elevation myocardial infarction; NYHA = New York Heart Association; PCI = percutaneous coronary intervention; PH = pulmonary hypertension; SIGN = Scottish Intercollegiate Guidelines Network; Sp_{O_2} = oxygen saturation as determined by pulse oximetry.
Shown are the British Thoracic Society 2011 guidelines with disease-specific recommendations for pulmonary and cardiac diseases (8).

Summary of the BTS guidelines 2011

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

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

	Levels of evidence
1++	High quality meta-analyses, systematic reviews of randomised controlled trials (RCTs) or RCTs with a very low risk of bias
1+	Well-conducted meta-analyses, systematic reviews or RCTs with a low risk of bias
1–	Meta-analyses, systematic review or RCTs with a high risk of bias
2++	High quality systematic reviews of case-control or cohort studies, or high quality case-control studies with a very low risk of confounding bias and a high probability that the relationship is causal
2+	Well-conducted case-control or cohort studies with a low risk of confounding or bias and a moderate probability that the relationship is causal
2–	Case-control or cohort studies with a high risk of confounding or bias and a significant risk that the relationship is not causal
3	Non-analytical studies (eg, case reports, case series)
4	Expert opinion

	Grades of recommendations
A	At least one meta-analysis, systematic review or RCT rated as 1++ and directly applicable to the target population; or a body of evidence consisting principally of studies rated as 1+, directly applicable to the target population and demonstrating overall consistency of results
B	A body of evidence including studies rated as 2++, directly applicable to the target population and demonstrating overall consistency of results; or extrapolated evidence from studies rated as 1++ or 1+
C	A body of evidence including studies rated as 2+, directly applicable to the target population and demonstrating overall consistency of results; or extrapolated evidence from studies rated as 2++
D	Evidence level 3 or 4; or extrapolated evidence from studies rated as 2+
✓	Recommended best practice based on the clinical experience of the Air Travel Working Party

Contraindications

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

Ahmedzai et al Thorax 2011;66:i1ei30

Transport of ventilator dependent patients

- Consult their ventilation specialist before arranging air travel
- Airline will need to know requirements at the time of reservation
- Doctor’s letter outlining the diagnosis, necessary equipment, recent blood gas results and ventilator settings
- Medical escort in intubated patients
- Take off and landing manual ventilation ventilator switched off
- Restricted to air ambulances in India and commercial airlines do not permit transport of such patients

Ahmedzai et al Thorax 2011;66:i1ei30

BTS 2002 vs BTS 2011

Table 1 Results of initial assessment

Screening result	Recommendation
Sea level Spo_2 >95%	Oxygen not required [B]
Sea level Spo_2 92–95% and no risk factor*	Oxygen not required [C]
Sea level Spo_2 92–95% and additional risk factor*	Perform hypoxic challenge test with arterial or capillary measurements [B]
Sea level Spo_2 <92%	In-flight oxygen [B]
Receiving supplemental oxygen at sea level	Increase the flow while at cruising altitude [B]

*Additional risk factors: hypercapnia; FEV_1 <50% predicted; lung cancer; restrictive lung disease involving the parenchyma (fibrosis,) chest wall (kyphoscoliosis) or respiratory muscles; ventilator support; cerebrovascular or cardiac disease; within 6 weeks of discharge for an exacerbation of chronic lung or cardiac disease.

Table 2 Results of hypoxic challenge test (15% Fio_2 for 20 minutes) with AHCPR grading (Appendix 2)

Hypoxic challenge result	Recommendation
Pao_2 >7.4 kPa (>55 mm Hg)	Oxygen not required [B]
Pao_2 6.6–7.4 kPa (50–55 mm Hg)	Borderline; a walk test may be helpful [C]
Pao_2 <6.6 kPa (<50 mm Hg)	In-flight oxygen (2 l/min) [B]

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

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

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

Pao_2, arterial oxygen tension; Spo_2, oxygen saturation.

Ahmedzai et al Thorax 2011;66:i1ei30

Summary

- Patients with chronic and acute lung diseases are at risk of hypoxia owing to the reduced ambient pressure resulting in hypobaric anoxia
- Resting sea level SpO2 and PaO2 do not correlate with hypoxemia at altitude
- Normobaric hypoxic challenge testing should be considered for patients with chronic and acute pulmonary diseases as they are potentially at risk of significant hypoxemia and complications during air travel
- A combination of SpO2 walk test blood gases and HCT may be best for assessing need for supplemental O2
- Possible to predict hypoxia during flight but there are no means of predicting symptoms or actual risk of harm during air travel
- O2 supplementation warranted in those with positive test
- Most airlines with adequate warning can provide oxygen at 2 or 4 litres per minute for respiratory patients