Assessment of Fitness for Air travel in Patients with Pulmonary Diseases

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- More than a billion people travel by air each year around the world

  Thorax 2002; 57: 289–304.

  Aviat Space Environ Med 2003; 74:A1–A19.

- Given the rising age of populations, the age of air travellers has also increased, with greater propensity for medical impairment.
- In flight medical emergencies, fourth leading cause is Respiratory.

Table 1—*Selected Surveys of In-Flight Medical Emergencies*

	Reference				
	61 (Speizer et al)	60 (Cummins and Schubach)	59 (Skjenna et al)	50 (Cottrell et al)	49 (Hordinsky and George)
Locus	Los Angeles	Seattle-Tacoma	Air Canada	United Air Lines	FAA
Period	10/1/85-3/31/86	9/1/86-8/31/87	1/1/88-12/31/88	7/1/86-6/31/87	8/1/86-7/31/87
No. of passengers ($\times 10^3$)	8,735	14,400	13,553	55,000	ns*
In-flight incidents, No. (%)	260 (0.003)	190 (0.001)	464 (0.003)	218 (0.0004)†	1,016†
Categories of incidents, No. (%)					
Cardiovascular	34 (13)	21 (20)	235 (50.6)	34 (15.6)	177 (17.4)
Respiratory	20 (7.5)	15 (7.9)	48 (10.3)	22 (10.1)	94 (9.3)
Neurologic	49 (18.8)	23 (12.1)	33 (7.1)	72 (33)	256 (25.2)
Gastrointestinal	69 (26.5)	28 (14.7)	59 (12.7)	ns*	109 (10.7)
Trauma	13 (5)	26 (13.7)	31 (6.7)	ns*	12 (1.2)
Other	76 (29.2)	60 (31.6)	58 (12.5)	90 (41.3)	368 (36.2)
Incidents/100,000 passengers	2.9	1.3	3.4	0.4	...
In-flight deaths, No.	7	0	2	3	9
Medical kit uses, No.	—	—	167	362	1,016

Gong H. Chest 1992;101;1104-1113

Flight is a Stress

- Preflight stresses
  - carrying baggage
  - walking long distances
  - being delayed
- Inflight stresses
  - Lowered barometric pressure and PiO_2
  - Noise, vibration (including turbulence)
  - Cigarette smoke
  - Uncomfortable temperatures and low humidity (10-20%)
  - Jet lag, and cramped seating

Rayman RB et al, Clinical aviation medicine, 3rd ed. New York: Castle Connolly Graduate Medical Publishing, LLC; 2000

1. The flight environment
2. Physiological effects of exposure to altitude
3. Respiratory disorders presenting a possible risk for potential air travelers
4. Clinical assessment for Air travel
5. Oxygen supplementation

Flight Environment

- Ordinary flights reach a cruising altitude between 25,000 and 45,000 ft asl (between 7,000 and 14,000 m asl)
- International laws stipulate that cabin pressure must not surpass that measured at 8,000 ft asl

  Code of Federal Regulations: Title 14, Part 25.841. Washington, Government Printing Office, 1986.
- Cottrell JJ conducted a study on 240 flights, barometric pressures measured in the aircraft cabins were between 5,000 and 8,000 ft asl with a mean of 6,214 ft asl

  Chest 1988; 93: 81–84.

- Higher levels of pressurization can
  - Decrease the energy available for other aircraft systems,
  - Reduce the operational lifetime of aluminium airframes,
  - Necessitate increased structural weight,
  - Which resulting in decreased fuel efficiency
- Hence commercial air craft are pressurized to 8000 ft (2450 m) asl for these technical reasons

- In cabins pressurized at 8,000 ft asl
  - Decrease barometric pressure 760 mm Hg at sea level to 565 mm Hg
  - Decrease PiO_2 150 to 110 mm Hg
  - FiO_2 21% to 15.1 % - 17.1%
  - PaO_2 100 mmHg to 53 - 64 mm Hg
  - SaO_2 99% to 85 - 91%
- Longer flights hrs are associated with progressive fall in cabin PO_2

Lee AP et al, *Paed Emerg Care 2002 18:78-80*

- The decrease in PiO_2 and the consequent decrease in PaO_2 lead to the increase in minute ventilation as a reflex.
- Healthy subjects have a wide ventilatory reserve; therefore, the increased minute ventilation is generally well tolerated.
- Respiratory patients may not tolerate exposure to even slightly hypoxic mixtures.
- The hypoxia-induced pulmonary vasoconstriction may further worsen the increase of the dead space and the pulmonary hypertension, which may further deteriorate the PaO_2

- Hypobaric hypoxemia
  - precipitate Respiratory Failure
- Expansion of gas in closed cavity
  - Can expand by 30% at 8000 ft (2450 m)
    - Pneumothorex
    - Pneumomediastinum
    - Air embolism
- Risk of DVT, PTE
- Spread of Infectious diseases

Respiratory disorders presenting a possible risk for potential air travelers

There is no absolute contraindications to air travel,
except pneumothorax, bronchogenic cyst and severe PAH

- Asthma
- COPD
- Pneumothorax
- Bronchogenic Cyst
- Restrictive Pulmonary Diseases
- Cystic Fibrosis
- Obstructive Sleep Apnoea Syndrome
- Pulmonary Hypertension
- Patients on LTOT
- Ventilator dependant patients
- DVT & PTE
- Pulmonary Infections

Asthma

- Asthma is the most frequent respiratory disease reported by air travelers

  Aerospace Medical Association, Air Transport Medicine Committee: Medical guidelines for air travel, ed 2. Aviat Space Environ Med 2003; 74:A1–A19.

- Around one third of in-flight respiratory emergencies are ascribed to asthma

  Cottrel JJ. JAMA 1989; 262: 1653-6

- Stable and well-controlled asthma:
  - no contraindications to air travel
- Unstable asthma/recent exacerbation:
  - avoid air travel

- Pre flight assessment is recommended
- Patients are advised to carry in hand baggage on board
  - Vital medicine including inhalers (reliever and preventer)
  - Course of oral steroids
- From April 2004, bronchodilator inhalers are included as part of the mandatory medical kit carried by aircraft on flights to and from the USA
- Portable battery-operated nebulisers may be used at the discretion of cabin crew
- Spacers are as effective as nebulisers

C O P D

- COPD pt are particularly susceptible to develop respiratory failure during flights

  Christensen CC et al,Eur Respir J 2000; 15:635–639.
  Johnson AO et al, Thorax 2003; 58: 729–732.
  Seccombe LM et al, Thorax 2004; 59: 966–970.

- In COPD patients, the ability to increase MV in response to the hypoxia is limited
- Even modest physical activity during the flight at high altitude can worsen their gas exchange

- High-risk COPD patients are those
  - Dyspnoea on exertion
  - Present hypercapnia
  - PaO_2 values < 70 mm hg or SaO_2 values < 92% at sea level
  - Maximal voluntary ventilation < 40 l/min

Mohr LC et al, Am J Med Sci 2008; 335: 71–79.

- Pre flight assessment is recommended
- Passengers should travel on a non-smoking flight
- Medicines and inhalers, as prescribed, should always be carried in the hand luggage on board
- Portable battery-operated nebulisers may be used/ spacer with MDI
- Patients prescribed in-flight oxygen should receive oxygen while visiting high altitude destinations

Pneumothorax

- Spontaneous pneumothorax or pneumomediastinum must be excluded before air travel.
- The air volume of a closed cavity can increase approximately 30% when moving from sea level to 8,000 ft asl
- The presence of a pneumothorax is an absolute contraindication to air travel
- The pneumothorax may critically increase during the trip

BTS recommendations. Thorax 2002; 57: 289–304.
Aerospace Medical Association: Aviat Space Environ Med 2003; 74:A1–A19
Fuchs HS et al, Aerosp Med 1967; 38: 1283–1285.

- Patients who have had a pneumothorax – CXR must before flight. Wait for seven days to elapse before flight.
- There is insufficient evidence to support six week delay after resolution, before travel.
- Traumatic pneumothorax - 2 wks after radiographic resolution
- Spontaneous Pneumothorax treated by surgical means - allowed to fly once they have recovered from the effects of their surgery
- Secondary Spontaneous Pneumothorax -The risk of recurrence is higher, may consider alternative forms of transport for one year of the initial event

BTS recommendations 2004

- Taveira-Da Silva et al done a retrospective study of 449 patients affected by ILD with high prevalence of spontaneous pneumothorax, showed that
  - There was a relatively low risk of pneumothorax following air travel.
  - No patient with pulmonary fibrosis or sarcoidosis presented with pneumothorax after air travel.
  - In patients with lymphangioleiomyomatosis, a 2.9% & 1.3 % frequency of a new pneumothorax in those who travelled by air and by ground respectively

Chest 2009; 136: 665–670.

- Although patients with extensive bullous emphysema may head for a bullae expansion but the available literature suggests that the real risk of pneumothorax is negligible

  Parker GW et al, Aeromed Acta 1961; 32:501–504

- Yanda et al, took 4 COPD patients with air trapping to a simulated altitude of 18,000 ft (5,488 m) and did not find evidence of worsening pulmonary function or pneumothorax.

  Aerosp Med 1964; 35: 1201–1203

- Tomashefski et al brought 6 COPD patients with blebs and bullae to a simulated altitude of 18,000 ft at a rate of 1,000 ft/min and found no radiographic evidence of bullae distention or pneumothoraces.

  Aerosp Med 1966; 37: 1158–1162

- The reason for the absence of pneumothoraces in these patients : bullae may likely communicate with the airways to a greater extent than expected, allowing pressure equalization.

Bronchogenic Cyst

- They are often asymptomatic, however emergencies may be caused by a sudden increase in the size and rupture of the cyst following a rapid decompression
- A few cases of cerebral air embolism have been reported in airplane passengers after bronchogenic cyst rupture
- Most of the cases were fatal
- Patients are advised against activities leading to rapid changes in ambient pressure, such as flying, diving or high altitude climbing or consider elective surgical treatment.

Zaugg M ET AL, Am J Respir Crit Care Med 1998; 157: 1686–1689.
Almeida FA ET AL, Chest 2006; 130: 575–577.
Belcher E et al, Eur Respir J 2007; 30: 801–804
Edwardson M et al, Neurocrit Care 2009; 10: 218–221

Restrictive Pulmonary Diseases

- Patients with a restrictive defect ILD or kyphoscoliosis, can develop a significant hypoxemia when exposed to hypoxic mixtures, simulating an air flight
- PaO_2 at the altitude correlated positively with the sea level PaO_2 and DLCO and negatively with $PaCO_2$
- The decreases in PaO_2 and SaO_2 worsened when patients performed modest physical activity during the test

Seccombe LM et al, Thorax 2004; 59: 966–970
Christensen CC et al, Eur Respir J 2002; 20: 300–305.
Chetta A et al, Aviat Space Environ Med 2007; 78: 789–792

- Patients with a restrictive defect, the ability to increase the minute ventilation in response to hypoxia is limited

Mohr LC et al, Am J Med Sci 2008; 335: 71–79.

- PaO_2 increased to acceptable levels with an O_2 supply of 2 L/min at rest and 4 L/min during exercise is given.

Christensen CC. Eur Respir J 2002;20:300-305

- Patients with severe restriction especially those with hypoxia should undergo pre flight evaluation or consider alternative forms of transport

BTS recommendations 2004

Cystic Fibrosis

- These patients are susceptible to the negative effects of hypobaric hypoxia at high altitude
- Moreover, the environment of the air craft cabin can represent a further risk factor, due to a significant decrease in cabin air humidity (12-22%)
- As comfortable humidity conditions are considered to be 40–70% relative humidity at sea level
- Low humidity could increase the risk of bronchospasm and retention secretions, leading to mucus plugs and probably atelectasis

- Pre flight assessment is recommended
- A full supply of all medication should be carried in the hand luggage to allow for delays and stopovers, preferably in the original packaging with pharmacy labels.
- Passengers should undertake physiotherapy during stopovers

Obstructive Sleep Apnoea Syndrome

- Periodic breathing and central apnoeas may occur in normal subjects during sleep at high altitude

  Weil JV : Principles and Practice of Sleep Medicine, ed 2. London, Saunders, 1989, pp 224–230.

- Patients affected by OSAHS, the respiratory pattern may deteriorate significantly while sleeping during a flight
- Patients with OSAHS treated with CPAP should be cautious and avoid long distance air trips.
- They should carry dry cell powered CPAP machine and avoid alcohol & sedatives before and during the flight

BTS Rec.Thorax 2002; 57: 289–304.
Prisant LM et al, J Clin Hypertens 2006; 8: 746–750

Pulmonary Hypertension

- Patients with both primary and secondary pulmonary hypertension are at high risk of complications during air travel
- There are individual variability to pulmonary vasoconstriction induced by hypoxia, even a light worsening of hypoxemia during flight can induce a significant increase in pressure in the pulmonary artery leading to a serious right cardiac failure

Mortazavi A et al, Aviat Space Environ Med 2003; 74: 922–927

- Severe (NYHA class III and IV) pulmonary hypertension as a contraindication to air travel

Mohr LC et al, Am J Med Sci 2008; 335: 71–79

Patients on LTOT

- Patients normally using LTOT should ensure they have LTOT throughout their stay
- Should increase flow of oxygen to add 2L/min
- Titration at hypoxia inhalation test is suggested
- Arrangements for oxygen in airport, stop over and transport to be arranges before hand
- Prior arrangement with the destination country is essential to ensure availability of supplies

Ventilator dependant patients

- Should have an escort competent enough to change the tube, perform suctioning and do manual breathing
- Carry an additional tracheostomy tube and battery driven suction machine
- Monitor cuff pressure (a little air needs to be removed during ascent and a little air be introduced on descent)

DVT & PTE

- The condition DVT itself is not dangerous, but the complication of PTE can be life threatening.
- "Economy class syndrome" term was first used by Symington and Stack in 1977, and again by Cruickshank et al. in 1988.
- This description wrongly implies that DVT does not occur in business or first class air travelers

- Up to 20% of the total population may have some degree of increased clotting tendency
- There have been no epidemiological studies published which show a statistically significant increase in cases of DVT when traveling in the absence of preexisting risk factors
- Factors which increase the likelihood of DVT (Virchow's triad)
  - Reduction in blood flow
  - Changes in blood viscosity
  - Damage or abnormality in the vessel wall

- It is unlikely that hypoxia or hypobaric changes are themselves etiological factors for VTE, as there is no reported increased incidence of VTE in
  - Populations living at high altitudes
  - patients with hypoxic lung disease
  - commercial airline pilots
- But Bendz B et al, reported that in the hypobaric environment of the aircraft, markers of activated coagulation may increase by twofold to eightfold.

Lancet 2000; 356: 1657-165.

- Sarvesaran found that 18% of sudden deaths over a three year period at Heathrow airport among long distance air travelers were attributable to PTE

Med Sci Law 1986; 26:35-83

- Air travel of more than four hours duration under taken within the preceding 4 weeks were the most common risk factors for PTE

Mercer A et al, Aviat Space Environ Med 1998; 69:154-7.

Ferrari E et al, Chest 1999; 115: 440-4.

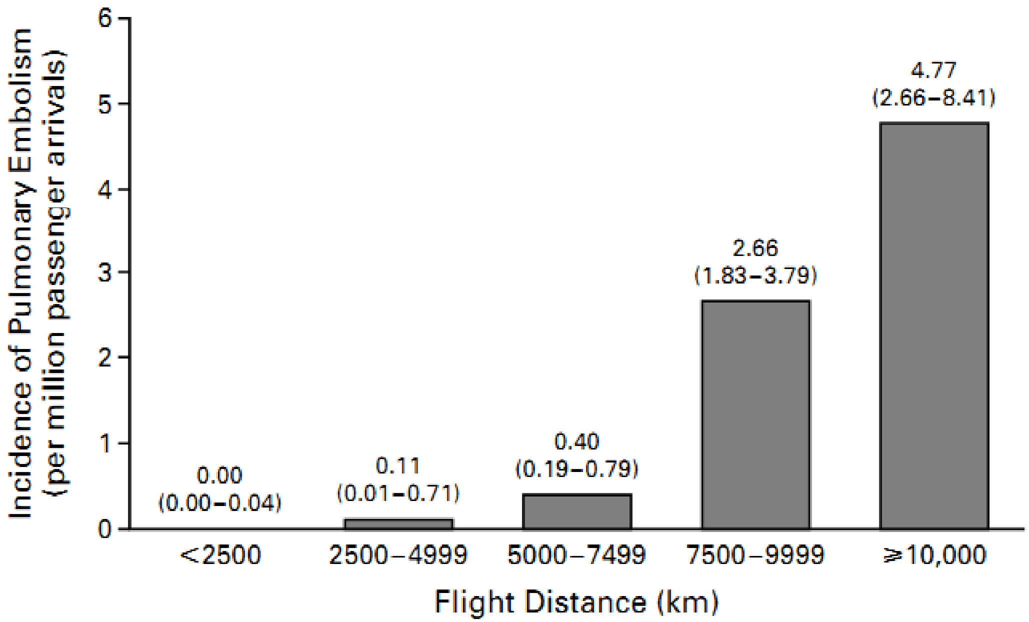
- Lapostol le et al ,systematically reviewed all cases of pulmonary embolism requiring medical care on arrival at France’s international airport From Nov 1993 to Dec 2000
- A total of 135.29 million passengers from 145 countries arrived at Charles de Gaulle Airport
- 56 had confirmed pulmonary embolism.
- The incidence of pulmonary embolism was much higher among passengers traveling more than 5000 km
- Incidence of DVT increases with distance traveled

  <5000 km - 0.01 case/million

  >5000 km - 1.5 case/million

  >10,000 km - 4.8 case/million

N Engl J Med 2001; 345:779-83.



Lapostol le et al, N Engl J Med 2001; 345:779-83.

- Philbrick J T et al done a systemic review from 1966 through December 2005 from MEDLINE
- totaling 25 studies (6 case-control studies, 10 cohort studies, and 9 randomized controlled trials)
- Concluded that all travelers, regardless of VTE risk, should
  - avoid dehydration
  - frequently exercise leg muscles.
  - Travelers on a flight of less than 6 hours and those with no known risk factors for VTE, do not need DVT prophylaxis.
- Travelers with 1 or more risk factors for VTE should consider graduated compression stockings and/or LMWH for flights longer than 6 hours.

	Risk Categories	Prophylaxis
Low Risk	Age over 40; obesity; active inflammation; recent minor surgery (within last 3 days)	Advice about mobilization and hydration, ± support tights/non-elasticated long socks
Moderate Risk	Varicose veins; heart failure (uncontrolled); recent myocardial infarction (within 6 weeks); hormone therapy (including oral contraception); polycythemia; pregnancy/postnatal; lower limb paralysis; recent lower limb trauma (within 6 weeks)	Passenger advised to consult own medical practitioner who may recommend the above + aspirin (if no contraindication) ± graduated compression stockings
High Risk	Previous VTE; known thrombophilia; recent major surgery (within 6 weeks); previous CVA; malignancy; family history of VTE	As above, but passenger's medical practitioner may recommend low molecular weight heparin instead of aspirin

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Pulmonary Infections
TB & Air Travel

- 1/3 of world population infected with MTB
- It is not possible to assess them medically before they fly.
- To date, no case of active TB has been identified as a result of exposure on a commercial aircraft.
- The quality of the air on board commercial aircraft is high and under normal conditions cabin air is cleaner than the air in most buildings.
- Prolonged journeys of more than 8 hours in a confined aircraft cabin may involve an increased risk of transmission

- The aircraft ventilation systems should continue to operate when the aircraft is delayed on the ground and the doors are closed. If not in operation, ground delays should be kept to less than 30 minutes
- **Infectious TB** : Pulmonary or laryngeal TB which are sputum smear-positive and culture-positive (if culture is available).
- **Potentially infectious TB**: Pulmonary or laryngeal TB which are sputum smear-negative and culture-positive.
- **Non-infectious TB**: Respiratory TB which have two consecutive negative sputum-smear and negative culture (if culture is available) results.
- People with infectious TB must postpone long distance travel (at least 2 wk after effective ATT started)
- MDR-TB patient must postpone any air travel

Clinical assessment for Air travel

- History & examination
- Spirometry
- SpO2
- ABG
- Walk test
- Hypoxemia Prediction Equations
- Hypoxia Altitude Simulation Test

Walk Test

50 m walk test

- Very simple test but not standardized
- It is considered a measure of the cardiopulmonary reserve to exercise

Mills FJ et al, BMJ 1983; 286: 1269–1271.
Lyznicki JM et al, Aviat Space Environ Med 2000; 71: 827–831

- The incapability to cover the 50 m distance or the onset of severe dyspnoea indicates that
  - A clinical and functional assessment require
  - The patient may require O_2 during the flight

6MWT

- It has been standardized and validated

ATS: Am J Respir Crit Care Med 2002; 166: 111–117
Chetta A et al, Respiration 2009; 77: 361–367

- It is widely used in lung function laboratories and the BTS recommends its use to evaluate the fitness to fly.
- The desaturation observed during the hypoxia altitude simulation test (HAST) is strictly correlated and predicted by the 6MWT-induced desaturation

Chetta A et al, Aviat Space Environ Med 2007; 78: 789–792.

Hypoxemia Prediction Equations

- The equations have been obtained by submitting the subjects to hypobaric rooms or to HAST and provide PaO_2 and SaO_2 values with 90% confidence intervals equal to ±7.5 mm Hg and to ±2–4%, respectively

BTS recommendations. Thorax 2002; 57: 289–304

- Equations have been published which predict the PaO_2 values at altitudes other than sea level

Equation	Authors	Used for
PaO_2 *ALT*, mm Hg = 22.8 – (2.74 · Alt, ft) + 0.68 · PaO_2 *SL*, mm Hg	Gong et al. [15]	COPD patients
PaO_2 *CAB*, mm Hg = 0.519 · PaO_2 *SL*, mm Hg + 11.855 · FEV_1, l – 1.76	Dillard et al. [23]	COPD patients
PaO_2 *CAB*, kPa = 0.74 + (0.39 · PaO_2 *SL*, kPa + (0.033 · DLco, % pred)	Christensen et al. [41]	Patients with restrictive defect

PaO_2 *ALT* = Predicted oxygen partial pressure at a certain altitude; Alt = expected altitude; PaO_2 *SL* = oxygen partial pressure measured at sea level; PaO_2 *CAB* = oxygen partial pressure expected at 8,000 ft (cruise altitude); FEV_1 = forced expiratory volume at 1 s; DLco = lung diffusion capacity for carbon monoxide. Conversion factors: 1 kPa = 7.5 mm Hg; 1 ft = 0.3048 m.

Gong H et al, Am Rev Respir Dis 1984; 130: 980–986.

Dillard TA et al, Ann Intern Med 1989; 111: 362–367

Christensen CC et al, Eur Respir J 2002; 20: 300–305.

Pulse oximetry

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 six weeks of discharge for an exacerbation of chronic lung or cardiac disease.

BTS guidelines Thorax 2002;57;289-304

Hypoxia Altitude Simulation Test

- The ideal test which exposes the subject to hypoxia in a hypobaric room but it requires complex and expensive equipment.
- Gong et al, proposed the so-called HAST, which is the most frequently used.
- In this test, subject is exposed to a hypoxic mixture of 15% oxygen and 85% nitrogen, from a Douglas bag, through a mouthpiece or a facial mask, connected to a two-way valve.

Am Rev Respir Dis 1984; 130: 980–986.

- SpO_2, PaO_2 and ECG monitored
- The exposure lasts for 20 min or until the pulse oximeter data reaches a stable condition
- This test is considered a reliable tool in predicting the hypoxemia measured during air travel both in healthy subjects and in COPD patients

Kelly PT et al, Aviat Space Environ Med 2006; 77: 1143–1147.
Kelly PT et al, Chest 2008; 133: 920–926.

Hypoxic challenge result	Recommendation
• $PaO_2 > 7.4$ kPa (> 55 mmHg)	Oxygen not required (B)
• PaO_2 6.6-7.4 kPa (50-55 mmHg)	Borderline. A walk test may be helpful (C)
• $PaO_2 < 6.6$ kPa (< 50 mmHg)	In-flight oxygen (2L/min) (B)

BTS guidelines Thorax 2002;57;289-304

- In case a significant hypoxemia occurs, the test must be repeated with oxygen supplementation through nasal cannula to titrate the necessary flow during the flight, starting with a flow of 2 l/min

Mohr LC et al, Am J Med Sci 2008; 335: 71–79.

Dine CJ et al, Chest 2008; 133: 1002–1005.

- In case of border line results it can be useful to perform a second test while the patient performs modest exercise, such as walking on a treadmill

Dine CJ et al, Chest 2008; 133: 1002–1005.

- COPD, cystic fibrosis or ILD the need of oxygen therapy during flight may be over estimated if the hypoxemia-predicted equations are considered instead of the HAST

Martin SE et al, QJM 2007; 100: 361–367.

- The HAST is considered the gold standard in the assessment of fitness for flight.

Dillard TA et al, Aviat Space Environ Med 2007; 78: 143–144.
Mohr LC et al, Chest 2008; 133: 839–842

Oxygen supplementation

- The need for oxygen should be disclosed when the patient books with the airline
- The airline medical department will issue a MEDIF form or their own medical form which to be completed by both the patient and the GP
- The airline’s Medical Officer then evaluates the patient’s needs

- Supplementary in-flight oxygen is usually prescribed at a rate of 2L/min
- Oxygen should be given by nasal cannulae.
- In-flight oxygen need not be switched on until the plane is at cruising altitude, and may be switched off at the start of descent.
- For patients on oxygen at sea level, the rate should only be increased while at cruising altitude.