

## Assessment of Fitness for Air travel in Patients with Pulmonary Diseases

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### ABSTRACT

During air travel, increasing hypoxia with altitude ascent is a potentially serious problem for patients with hypoxemic chronic airway obstruction (CAO). Travel by air is the most popular way of transport nowadays & estimated that each year worldwide, more than 3 billion passengers travel by air & 736 million in the United States alone.

For most passengers, even those with respiratory disease, air travel is safe and comfortable. Some patients with COPD & other Chronic Lung diseases may be at risk but, with screening, these patients can be identified and most of them can travel safely with supplemental oxygen.

Some patients with chronic lung disease may have mild hypoxemia at sea level but during air travel in a hypobaric hypoxic environment, compensatory pulmonary mechanisms may be inadequate despite normal sea-level oxygen requirements. In addition, compensatory cardiovascular mechanisms may be less effective in some patients who are unable to increase cardiac output. Air travel also presents an increased risk of venous thromboembolism.

It's estimated that, almost 1 medical emergency for every 600 flights. Respiratory symptoms accounted for 12% of all these in-air emergencies.

**Key words:** Hypoxia, Hypoxic challenge testing, Chronic airway disease, high altitude.

### BACKGROUND

Millions of tourists travel by air annually. Many unsuspecting and otherwise healthy individuals may get sick at high altitudes. Individuals with pulmonary and cardiac disorders are particularly at risk of developing hypoxemia at altitude. In a commercial airliner flying at high altitude, the reduced cabin air pressure means that all passengers are exposed to slightly lowered oxygen levels (hypoxia) equivalent to an altitude of approximately 5,000 to 8,000 ft. It is well known that severe hypoxia results in constriction of blood vessels in the lungs (a phenomenon called hypoxic pulmonary vasoconstriction), which in turn causes an increase in the blood pressure in the lungs (pulmonary arterial pressure).

Our objective is to describe the normal and maladaptive physiological responses to altitude-related hypoxia, to review existing methods and guidelines for preflight assessment of air travelers, and to provide recommendations for treatment of hypoxia at altitude.

### Hypoxia-related altitude sickness

Hypoxia, or atmosphere with low oxygen availability, can affect a person's physical and mental performance. Altitudes related hypoxic symptoms are generally observed higher than 3000 m. Although the high altitude is defined as beginning at an elevation of 1,500

m (5,000 feet), symptoms are rarely present at 1,500 m but become increasingly common with rapid ascent to higher elevations<sup>1</sup>.

As per international regulation, all Commercial aircraft maintained optimum pressure during flight because passengers could not survive exposure to the low atmospheric pressure at the usual cruising altitude (10000–13500 m). Though the atmospheric pressure of 760 mm hg is most comfortable, if it can be maintained during travel through high altitudes but for reasons of aircraft weight and fuel economy, it is impractical to maintain cabin pressure at sea level pressure 760 mm Hg ( 101.325 Kpa) but international regulations do not allow cabin pressure to fall below 74 kPa (555 mmHg) the equivalent of atmospheric pressure at 2450 m(8000ft) except in emergencies. Cruising altitudes of commercial aircraft typically range from approximately 30,000 to 40,000 feet, but at times may reach altitudes of 60,000 feet<sup>2</sup>. However, the cabin altitude pressure is maintained at approximately 8,000 feet (2450 m) equivalent to 74 kPa (555 mm Hg)<sup>3</sup>. Pressurization of the aircraft cabin is achieved using exterior air that is compressed and mixed with filtered and recirculated cabin air. Up to 50% of the cabin air is not recirculated and is expelled, to be replaced with exterior air, with 20–30 complete air exchanges occurring per hour<sup>4</sup>. As the aircraft

ascends, the decreasing cabin air pressure results in gas expansion, which can cause a “popping” sensation in the ears of passengers due to air escaping from the middle ear and the sinuses.

### Effects on passengers & crews

Hypoxia is defined as having a low level of oxygen in your body tissues. It can be responsible for difficulty breathing, a rapid heart rate, restfulness, confusion, and a bluish-colored skin tone. Hypoxia can be life-threatening. In healthy passengers the hypoxia of the aircraft cabin will result in only mild hypoxemia; arterial oxygen tension (PaO<sub>2</sub>) falls to about 8 kPa (60 mmHg) but the shape of the oxyhemoglobin dissociation curve prevents any fall in oxygen saturation (SaO<sub>2</sub>) below about 92%<sup>5</sup>.

The effects of the earth's gravity also play an essential role in the amount of oxygen in the air we breathe. At sea level, gravity keeps oxygen molecules closer together, making it easy for us to breathe. As you increase altitude, the distance between the molecules gets further and further apart, so the amount of oxygen molecules we breathe in at 18,000 feet is half of what we breathe in at sea level.

Patients with chronic lung disease may not tolerate this mild degree of hypoxia and may become significantly hypoxemic. Schwartz et al<sup>4</sup> studied 13 subjects with COPD exposed to an altitude of 2250 meters (8000 feet) in whom arterial blood gas tensions were measured at sea level and that at altitude. Mean PaO<sub>2</sub> fell from 9.0 kPa at sea level to 5.9 kPa (2250 meters), a level which most physicians would regard as undesirable although none of these subjects developed any symptoms. PaCO<sub>2</sub> fell from 5.4 kPa to 4.8 kPa. Individuals may be at increased risk of significant hypoxemia, even at altitudes within the normal operating range of the aircraft. Compensatory mechanisms in patients with pulmonary or cardiac disease may also be less effective, placing these patients at further risk of significant hypoxemia<sup>6</sup>.

In expiratory flow-limited patients (e.g., COPD, Asthma), an increase in minute ventilation may result in hyperinflation, and further exacerbate respiratory discomfort. In patients with restrictive lung disease (e.g., interstitial lung disease, kyphoscoliosis, and obesity), although an increase in minute ventilation may occur, this may also be limited as preexisting

impairment of gas exchange may attenuate other compensatory mechanisms. Other conditions contributing to high-altitude hypoxemia and in-flight complications include obstructive sleep apnea, pulmonary hypertension, pneumothorax, and cystic fibrosis<sup>6</sup>

In many of these conditions, even at rest, hypoxemia can result in respiratory symptoms, and critical end-organ dysfunction such as arrhythmia or syncope can occur<sup>7</sup>. Furthermore, patients with cardiovascular disease may be unable to adequately increase cardiac output, which could further worsen hypoxemia and exacerbate end-organ hypoxia.

### Fitness to fly assessment

The air we breathe at ground level contains 21% oxygen but when we travel by air this drops to 15%. If you suffer from lung disease this drop in oxygen may make you breathless or cause other problems which can be dangerous to your health. A pre-flight assessment can help identify if you may develop such problems.

The aim of the test is to create similar conditions to those on board an aircraft. To achieve this you will be asked to breathe a gas mixture that contains 15% oxygen for up to 20 minutes. During the test, we will monitor your heart rate and oxygen levels. We will also take a small sample of blood from your earlobe to gain a more detailed picture of your oxygen levels after breathing the gas mixture. If your oxygen levels drop during the test, some extra oxygen will be given to bring it up to normal levels. We can then decide if you would need to have extra oxygen during a flight and how much oxygen you would need. The assessment also includes a lung function test where we will ask you to take a big breath in and blow the air out down a tube. This allows us to measure the airflow through your lungs to help your consultant decide how safe it is for you to fly.

To date, assessment of fitness to fly in patients with pulmonary disease has largely been studied in patients with COPD, although patients with restrictive lung disease and cystic fibrosis have also been studied<sup>7,8</sup>.

## Pre-flight risk assessments

### History, Physical Examination, and Spirometry

Pre-flight risk assessments are currently recommended for both restrictive & obstructive lung disease patients. As part of a preflight risk evaluation, medical history, and physical examination should be performed. Co-morbid conditions such as cardiovascular disease, cerebrovascular disease, other neurological diseases, and anemia should be evaluated. Any previous flying history should therefore be explored, as this may yield important information as to symptoms or complications that may have occurred during or after air travel.

In the absence of any contraindication, spirometry should be performed on patients with a history of acute or chronic lung disease or with symptoms suggestive of lung disease. Contraindications would include pneumothorax, massive hemoptysis, recent chest surgery, and tuberculosis. Pulse oximetry at rest should also be done, with arterial blood gas confirmation in addition to this if hypercapnia is suspected.

### Assessing the Risk for Hypoxemia

Several methods to assess hypoxemia risk during air travel are available<sup>9</sup>. These include sea-level measurement of SpO<sub>2</sub> and PaO<sub>2</sub>, the use of equations to predict hypoxemia at altitude, and also hypoxic challenge testing (HCT), performed under either normobaric or hypobaric conditions. Compared with other methods, the use of SpO<sub>2</sub> measurements at sea level to risk stratify has become recognized as a less reliable predictor of in-flight SpO<sub>2</sub><sup>8</sup>.

In the 2002 BTS guidelines, an SpO<sub>2</sub> of 92–95% without risk factors or SpO<sub>2</sub> greater than 95% was used to indicate that no further testing was warranted<sup>9</sup>. Among 100 patients with COPD who were stratified on the basis of SpO<sub>2</sub> thresholds from the 2002 BTS algorithm and then underwent pulse oximetry and normobaric hypoxic challenge testing, the sensitivity and specificity for these SpO<sub>2</sub> thresholds were only 59% and 72%, respectively<sup>9</sup>. Thus, a lower-normal SpO<sub>2</sub> even without risk factors is no longer considered a sufficiently robust test by which to screen patients, and additional hypoxic challenge testing is recommended.

Hypoxic challenge testing in normobaric condition is now the preferred method to assess risk of hypoxemia at high altitudes. It is becoming more widely available and correlates well with other means of assessment.

SpO<sub>2</sub> decreased from 95% at sea level to 86% in flight, which compared well with hypoxic challenge testing with a sea-level SpO<sub>2</sub> of 96%, decreasing to 84% at simulated altitude. Hypoxic challenge testing correlated strongly with actual flight data ( $r = 0.84$ ).

### Hypoxic Challenge Testing Results

According to the published literature by the American College of Chest Physicians, Any patient with a resting oxygen saturation level determined by pulse oximetry of <92% should receive inflight supplemental oxygen<sup>10</sup>. Patients with baseline oxygen saturation level determined by pulse oximetry of 92%–95% (and some patients with underlying lung disease and oxygen saturation level determined by pulse oximetry of >95%) should undergo a Hypoxic Challenge test (HCT) before air travel. This Hypoxic Challenge Test is designed to determine whether you will need supplemental oxygen to fly. This is necessary because on an airplane the pressurized cabin reduces the level of oxygen in the air from 21% to 15%, which can mean some patients with lung conditions require extra oxygen to fly safely.

As per British thoracic society guidelines (2011), after the administration of a 15% fractional concentration of inspired oxygen for 20 minutes, a PaO<sub>2</sub> greater than 50 mm Hg or a SpO<sub>2</sub> of at least 85% could suggest that in-flight oxygen is not required. However, pulse oximeter or arterial blood gas values less than that require oxygen supplementation via nasal cannulas<sup>11</sup>.

### Supplemental Oxygen therapy

If the hypoxic challenge test is positive, titration of supplemental oxygen can be performed. However, this presents a number of challenges with normobaric testing. Compared with titration during hypobaric testing, there is an underestimation of supplemental oxygen requirements<sup>12</sup>, which may reflect poorer accuracy in terms of the actual FIO<sub>2</sub> administered during a normobaric test with supplemental oxygen. In addition, during a normobaric or hypobaric hypoxic challenge test, pulsed dose oxygen may result in a lower PaO<sub>2</sub> than continuous flow oxygen<sup>12</sup>. Continuous flow oxygen may be delivered at rates of up to 6 L/minute depending on the portable concentrator used. Pulsed dose flow rates also vary depending on the portable oxygen concentrator used.

## Arrangement of Supplemental Oxygen for Travel

U.S. Department of Transport ruling implemented a jurisdiction from 2009, that “Nondiscrimination on the Basis of Disability in Air Travel,” all airlines traveling to and from the United States are required by law to permit passengers to carry their portable oxygen concentrators (POC), provided that have been approved for use by the Federal Aviation Administration (FAA). The list of portable concentrators currently approved for use by the FAA, and those currently approved by the 10 largest airlines worldwide are available online in the airline’s website.

But a number of challenges are faced by passengers with respect to arranging the use of portable concentrators. Patients must provide at least 48 hours’ notice of travel plan, together with a physician statement for how and when the POC is to be used during the flight. Some airlines do not guarantee a power outlet for use of the POC and instead recommend ensuring the machine is fully charged and those additional charged batteries are also carried. Finally, some airlines require patients to assume all risk by signing a waiver of liability before air travel.

## Disease specific consideration

### • Interstitial or Restrictive Lung Diseases

In patients with co morbidity, including Pulmonary hypertension 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 SpO<sub>2</sub> falls to <95% on exercise, and/or in those in whom either Transfer Factor Carbon Monoxide (TLCO) ≤50% or PaO<sub>2</sub> ≤9.42 kPa (if available).

Patients with TLCO <50% of predicted or PaO<sub>2</sub> ≤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 CO<sub>2</sub> retention, titration HCT is advised to determine the oxygen flow rate. (BTS-2022)

The patient should also bring a course of oral corticosteroids and antibiotics in the event of an acute exacerbation of their disease

### Neuromuscular Disease or Chest Wall Disease

Patients with neuromuscular disorders (NMD) can develop ventilatory impairment due to respiratory

muscle weakness but despite disability, many travel by air. The British Thoracic Society (BTS) recommends HCT in those who have baseline oxygen saturation (SpO<sub>2</sub>) at sea level between 92–95%. However, this recommendation is based on very limited evidence.

### Cystic Lung Disease

In addition to hyperinflation within communicating airways, at an altitude of 8,000 feet, Boyle’s law predicts there will be a 38% increase in the size of closed air-filled pockets within the body This gas expansion may be associated with an increased risk of pneumothorax in patients with bullous or cystic lung disease. However, from published data in patients with cystic lung disease, the incidence of pneumothorax related to air travel appears to be low<sup>13</sup>.

### Air travel after pneumothorax

Closed pneumothorax patients should not fly on a commercial flight. It is currently recommended that patients not travel after a pneumothorax unless drainage has been performed and, in the case of recurrent pneumothorax, when definitive surgical treatment has occurred<sup>14</sup>. Otherwise, provided chest imaging has determined the pneumothorax has resolved, patients should be safe to travel after 7 days have elapsed. However, Patients with preexisting lung disease have a high risk of recurrence, and that this risk remains increased for up to 1 year after a pneumothorax.

### Air Travel after Chest Surgery

Air travel should be delayed for at least 2 weeks after uncomplicated chest surgery, and confirmation of resolution of any pneumothorax or collected air by chest radiography is recommended. A careful medical assessment is required before travel. This should include consideration of their baseline status including co-morbidities, SpO<sub>2</sub>, post-procedure complications such as infection and/or pain, flight duration, and destination. The opinion of the relevant surgeon or interventionalist should be obtained before the patient travels by air.

### Air Travel after Bronchoscopic procedures

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 post procedure chest X-ray should wait for 1 week before air travel.

## Asthma

Necessary medications including metered dose inhaler (MDI) and spacer devices should be carried in hand luggage to mitigate the risk of lost or missing hold baggage & salbutamol inhalers and spacers, must be immediately accessible<sup>14</sup>.

- 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.
- 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.
- *Hypoxic Challenge test should however be considered for those with severe asthma, regardless of baseline sea level oxygen saturation.*

## Chronic obstructive pulmonary disease

Patients with well-controlled COPD are permitted to 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.  
*COPD patients 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*<sup>15</sup>.

## 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 cannula. If there are concerns about hypercapnia, HCT should be considered if available<sup>16</sup>.
- Those eligible for LTOT (sea level PaO<sub>2</sub> <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.

## Bronchiectasis

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

## Respiratory tract infection

### Viral infections

Patients suffering from or suspected for contagious infections including measles, chickenpox, mumps, *Severe acute respiratory syndrome* (SARS), Middle East respiratory syndrome (MERS) or COVID-19 should not be allowed to travel until they are considered non-infectious.

### Tuberculosis

Smear positive patients must not fly until they have provided two smear negative. 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<sup>17</sup>. 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.

## Obstructive Sleep Apnea (OSAS) and Obesity Hypoventilation Syndrome (OHS)

Wherever possible, daytime flight are advisable 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 an adjustment is required for operation at altitude. Airline approval for carriage and use of the device, including battery specification, must be gained before travel<sup>18</sup>.

## 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<sup>19</sup>.

## Air travel after VTE

Air travel should be delayed for 2 weeks after a diagnosis of DVT or pulmonary embolism (PE). 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. 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<sup>20</sup>.

## CONCLUSION

Air travel carries the risk of complications, particularly in patients with a history of lung disease. Patients with risk factors for in-flight hypoxemia should undergo a history examination, physical examination, and pulse oximetry. Patients with resting oxygen saturation level in room air lower than 92% should receive in-flight additional oxygen. The hypoxic challenge test is strongly recommended prior to flying as a screening tool for patients with baseline pulse oximetry-determined oxygen saturation between 92% and 95% and in certain patients with underlying lung disease with oxygen saturation level between 95% and 100%.

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