

Recommendations for patients with chronic respiratory disease considering air travel: A statement from the Canadian Thoracic Society

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Patients with respiratory disease regularly seek the convenience of commercial airline travel. In addition to the stresses that all patients with chronic disease encounter, these patients are exposed to the affects of acute altitudinal hypoxemia. This in turn has the potential to produce significant symptoms and complications in-flight for patients with chronic respiratory disease. This article reviews the current literature, and seeks to help the practicing physician by providing recommendations on which patients should be assessed pre-flight, the type of assessment that should be carried out and recommendations for providing advice to these travelling patients.

Key Words: *Air travel, Altitude, COPD, Guidelines, Hypoxemia, Oxygen therapy*

This article was written to provide assistance to physicians faced with assessing patients with chronic respiratory disease who wish to travel by commercial airline. The following recommendations are proposed by the Canadian Thoracic Society Standards Committee after review of the English language literature, consultation with experts in the area, and critique by members of the Standards Committee.

Recommandations pour les malades pulmonaires chroniques souhaitant voyager par avion : prise de position de la Société canadienne de thoracologie

RÉSUMÉ : Pour des raisons de commodité, les malades pulmonaires chroniques envisagent souvent de voyager par avion. En plus du stress que tous les malades avec une affection chronique rencontrent généralement, les malades pulmonaires chroniques s'exposent également aux effets d'une hypoxémie aiguë due à l'altitude, et qui peut, au cours du vol, provoquer chez eux des symptômes et des complications importants. Le présent article passe en revue la littérature actuelle et souhaite aider le praticien en lui fournissant des recommandations concernant l'évaluation des patients avant un voyage par avion, le type d'évaluation à effectuer, et les conseils à donner à ces patients qui voyagent.

Unfortunately, the state of the art is plagued by a lack of objective scientific data. Therefore, these recommendations are not supported by large, randomized, controlled trials, but rather reflect data from several small studies testing various interventions (1-10) and reviews by experts on the topic (11-17). These recommendations will evolve with greater clinical experience and publication of new information.

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SCOPE OF THE PROBLEM

Air travel has become a preferred mode of travel with an estimated more than 12 million passengers per year traveling on commercial airlines in Canada (18). Although no accurate statistics are available, it is reasonable to estimate that a percentage of these travellers have chronic cardiac or respiratory disease as the prevalence of chronic obstructive pulmonary disease (COPD) alone approaches 3% to 5% in the population (4,17). With increasingly proactive attitudes coupled with advances in drug therapy, oxygen delivery systems and rehabilitation programs, increasing numbers of patients are seeking the freedom of air travel. While patients with any chronic disease frequently encounter logistical problems while travelling, those with respiratory disease may have the added problem of acute altitudinal hypoxemia (1,6,16,17, 19-22). Although many patients with severe disease have chronic hypoxemia at ground level, others with milder disease may only become hypoxemic when exposed to the lower ambient partial pressure of oxygen that occurs during commercial air travel.

The patient with chronic respiratory disease may encounter many potential barriers to successful air travel. Some of the major obstacles are the physiological effects of exposure to hypobaric hypoxemia, additive effects of medications, the physical stress and fatigue of travel, disruption of usual schedules, increased costs of travel, necessity of arranging for a travel companion, logistics of transporting respiratory equipment and oxygen, and difficulties in arranging for and the cost of in-flight oxygen. In this review, we will focus on the problem unique to the patient with respiratory disease, which is the effect of acute hypobaric hypoxemia. In doing so, we will provide general recommendations for the assessment and treatment of patients with respiratory disease considering air travel.

PHYSIOLOGICAL EFFECTS OF AIR TRAVEL

Effect of commercial air flight on ambient partial pressures of oxygen: Commercial jet aircraft vary in their routine cruising altitudes from 6700 m to 13,400 m above sea level. Although the interior of the cabins is partially pressurized, cabin pressures are not maintained at ground level equivalents because of concerns with operating efficiency, structural integrity (frequent pressurization-depressurization cycles can weaken the aircraft structure) and cost effectiveness. The maximum amount of cabin pressurization capacity is fixed on a given aircraft and is generally greater in newer aircraft, which are designed to fly at higher altitudes (2). Cottrell (3) used altimeters to measure effective in-flight cabin altitudes on 16 different types of aircraft during 194 American domestic and 10 intercontinental, regularly scheduled commercial flights. The mean in-flight cabin altitude was 1724 ± 615 m (mean \pm SD) with a median of 1894 m. There were significantly higher pressures in newer generation aircraft (median 2259 metres) versus older generation aircraft (median 1846 metres). Hence, at normal cruising altitudes, cabin pressures may range from 565 to 690 mmHg. Once the plane is airborne, the cabin pressure may not remain constant

while the aircraft changes altitudes to avoid turbulence. Therefore, preflight prediction of cabin pressures is approximate at best.

Although the proportion of oxygen in ambient air always remains constant, at approximately 21%, the falling barometric pressure with increasing altitude results in lower PO_2 . The PO_2 in inspired air falls approximately 4 mmHg for every 300 m of altitude (17). An effective cabin altitude of 1724 metres results in an inspired PO_2 of 118 mmHg compared with 149 mmHg at sea level. However, the wide range of in-flight cabin pressures noted by Cottrell (3) means that inspired oxygen pressures may vary from 106 to 135 mmHg. In a subject with normal respiratory function, this means that the PO_2 in arterial blood (PaO_2) will change from approximately 100 mmHg at sea level to 55 to 85 mmHg during commercial air flight (assuming normocapnia). Although these effects on the partial pressures of oxygen in the blood of normal subjects are known, there has been relatively little investigation into how this environment affects patients with compromised respiratory function.

Physiological effects on patients with chronic respiratory disease: The ascent to high altitude results in reduced inspired oxygen pressure with an associated decrease in PaO_2 . Normal subjects adapt very quickly to this hypoxemia by increasing minute ventilation (primarily by increasing tidal volume) and correcting PaO_2 (12,14,17,19,20,23-25). However, patients with acute or chronic lung disease, whose PaO_2 is already low and on the steep portion of the oxyhemoglobin dissociation curve at ground level, may not have the reserve to increase ventilation, which may leave them significantly hypoxemic in-flight. The situation may be further worsened by exertion, hypoxemia-induced pulmonary hypertension resulting in decreased cardiac output, low ambient humidity causing difficulty with drying of secretions, fatigue and sleep deprivation, hypoventilation during sleep, exposure to cigarette smoke and carbon monoxide, and the effects of alcohol, sedatives and medications.

However, despite the potential risks, there is little objective data on the incidence of hypoxemia and hypoxemia-induced symptoms and complications in patients with lung disease travelling on commercial airlines. In part, this may be because the exposure to hypoxic conditions for most travellers is brief, lasting only a few hours at most, and the early symptoms of hypoxemia such as dyspnea, euphoria, impaired judgement and mental confusion are often subtle and may go unreported. It also appears that true emergencies are relatively rare. Skjenna et al (18) reviewed medical incidents requiring a nurse, physician or paramedic on board Air Canada flights from 1982 to 1988 and found that from 221 to 464 incidents occurred per year with an average of 2.9 deaths per year. Cardiovascular disease was by far the most common problem, with respiratory disease accounting for approximately 10% of these incidents. Speizer et al (26) surveyed passenger arrivals at Los Angeles International Airport and found that 260 (0.003%) of 8.7 million arrivals had significant in-flight medical problems. Twelve of these patients had exacerbations of COPD. Cummins et al (27,28) in an eight-

year survey of 42 international airlines found reports of 577 in-flight deaths, of which 56% were reported as cardiac related and 6% were classified as respiratory related. The information gathered in these studies was retrospective and incomplete, and it is not known what proportion of these patients were chronically hypoxemic or required oxygen supplementation.

In addition to these clinical observations, several scientific studies examining the effects of either hypobaric hypoxemia (1) or normobaric hypoxemia (4,27) did not report significant adverse clinical events. However, these studies used selected small numbers of stable patients and studied them for relatively brief periods of 1 h or less. These subjects did not have additional stresses such as fatigue, sleep deprivation, medication or exercise. Unfortunately, evaluating patients for the effects of hypoxemia can be difficult. The initial effects of hypoxia are often insidious, with euphoria and decreased cognitive function occurring some time before more overt findings such as seizures or loss of consciousness. Individual tolerance may also vary considerably, while smoking, cardiac disease, anemia, alcohol and some drugs can potentiate or confuse the effects. A theoretical but undocumented risk is the possibility of hypoxemia induced cardiac arrhythmias occurring during the flight. At this point, there is a need for methodologically sound prospective evaluation.

Prediction of in-flight PaO_2 : The PaO_2 while in-flight is probably the most important factor determining the ability of the patient with chronic lung disease to fly safely. While this has led to considerable interest in the accurate prediction of in-flight PaO_2 , the measured in-flight PaO_2 is determined not only by the altitude, but by the patient's ability to respond appropriately by increasing ventilation. In addition, other complicating factors such as fatigue, sleep deprivation, alcohol, medications, etc, make accurate prediction extremely difficult. However, a number of studies have attempted to address this issue using several techniques including actual measurements in-flight, hypobaric chambers in the laboratory, and by inhalation of hypoxic gas mixtures in the laboratory (1,4,5,29), with the majority of studies carried out on subjects with stable COPD.

Several investigators have studied the use of regression equations as a means of predicting in-flight PaO_2 in stable groups of patients with COPD and restrictive lung disease (1,5,29). Gong et al (29) studied the effects on patients with respiratory disease who inhaled oxygen concentrations of 17%, 15% and 14% which correspond to the ambient PO_2 experienced at 1500 m, 2400 m and 3000 m, respectively. A regression equation proposed by these investigators for patients with stable COPD is

$$\text{altitude } PaO_2 = 22.8 - 2.74x + 0.68y$$

where x is altitude in thousands of feet and y is sea level PaO_2 . A similar predictive equation for patients with restrictive lung disease proposed is

$$\text{altitude } PaO_2 = 25.0 - 3.12x + 0.62y$$

Dillard et al (1) studied 18 patients with emphysema (forced expiratory volume in 1 s [FEV_1] = 0.97 ± 0.32 L) and nine normal subjects using a hypobaric chamber comparing sea level with a simulated altitude of 2400 m (barometric

pressure 565 mmHg). At sea level, the COPD patients had a PaO_2 of 72.4 ± 9 mmHg with a fall to 47.4 ± 6 mmHg at altitude while $PaCO_2$ was 38 ± 4 mmHg at sea level and 35 ± 4 mmHg at altitude. Normal subjects had a fall in arterial PO_2 from 95.6 ± 8 mmHg at sea level to 59.8 ± 4 mmHg at altitude with a $PaCO_2$ of 39 ± 4 mmHg at sea level and 34 ± 4 mmHg at altitude. No patients developed significant symptoms at altitude for 45 mins, and the best fit equation to describe the regression was

$$PaO_2 \text{ at altitude} = 0.410 (PaCO_2 \text{ at sea level}) + 17.652$$

They also found FEV_1 to have additional predictive value. Others (5,29) have also tried to develop regression formulas to predict PaO_2 at altitude; however, their complexity limits their practical use. Predictive equations may also be influenced by factors such as timing of arterial blood gas samples because Schwartz et al (4) demonstrated that measurement of ground level PaO_2 2 h before flight gave a better predictive value than measurements made weeks before. If predictive equations are to be used, a ground level blood gas should probably be determined within days of travel in a clinically stable patient. Prediction equations may ultimately prove useful for selected patients; however, they are limited to specific conditions and cannot account for unexpected variations in effective cabin altitude or other complicating factors. They do not predict PaO_2 during in-flight exertion and are not accurate for patients with hypercapnia or who are already on supplemental oxygen. More important, they remain to be validated in the general population.

From a clinical perspective, the most practical objective preflight evaluation is probably obtained by assessing the patient while he or she is breathing hypoxic gas mixtures in a pulmonary function laboratory or monitoring in a hypobaric chamber. Such testing also allows measurement of the amount of supplemental oxygen required to maintain adequate oxygenation in-flight. Although hypobaric chambers are an attractive method, their lack of availability makes them inaccessible to most physicians. A practical alternative is to monitor oxygenation by pulse oximetry or arterial blood gases while breathing a hypoxic gas mixture containing 15% oxygen, which corresponds to an altitude of 2400 m (4,17,29). Assessment for this altitude is recommended as a worst case scenario for commercial air travel.

ROLE OF THE PHYSICIAN

The role of the physician is to provide advice to prospective air travellers with the objective of preventing untoward difficulties during flight. Patients at risk for problems during air travel need to be identified, appropriately evaluated, and prescribed the necessary treatments to prevent problems from arising in-flight. It then becomes the responsibility of the patient to make the necessary arrangements to fulfil the airline's requirements and the responsibility of the airline to ensure the safety of the patient and other passengers during flight.

RECOMMENDATIONS

Who to evaluate before air travel: The following patients should be considered for evaluation (Table 1).

- Patients with known or suspected hypoxemia

TABLE 1

Whom to evaluate for potential hypoxemia before air travel

Patients with known or suspected hypoxemia
Patients with known or suspected hypercapnia
Patients with known chronic obstructive lung disease or restrictive lung disease
Patients who already use supplemental oxygen
Patients with a history of previous difficulty during air travel
Patients with recent exacerbation of chronic lung disease
Patients with other chronic conditions that may be exacerbated by hypoxemia

Patients with a documented PaO_2 of less than 70 mmHg at sea level (or equivalent for their local altitude) should be evaluated for supplemental in-flight oxygen because these patients will have a predicted in-flight arterial oxygen tension of 50 to 55 mmHg or less.

- Patients with known hypercapnia

Although the risk associated with hypercapnia has not been systematically studied, intuitively these patients are at higher risk. A study evaluating 21 patients who flew a commercial airline to centres for lung transplantation or thromboembolectomies (4) reported seven patients who had a $PaCO_2$ greater than 40 mmHg (mean 48.8, SD 10.1). Of these patients, four had in-flight complications including two syncopal episodes, one with persistent hypoxemia not responding to oxygen supplementation, and one death. Of the 14 nonhypercapnic patients, only one patient had a complication that was a syncopal episode. Hypercapnic patients requiring oxygen supplementation may be at even greater risk if they require increased oxygen supplementation in-flight.

- Patients with known COPD or restrictive lung disease with impaired lung function

Lung function studies indicating significant physiological impairment suggest a significant risk of hypoxemia and identify a need for objective measurement of oxygenation (1).

- Patients with known chronic hypoxemia requiring supplemental oxygen

Patients already requiring supplemental oxygen require re-evaluation before travel. In general, these patients require an increase in the supplemental oxygen flows by 1 to 3 L/min (12,13).

- Patients with a past history of possible hypoxemia-related symptoms during air travel

These symptoms might include dyspnea, chest congestion, syncope or nonspecific symptoms, such as lightheadedness, confusion or weakness.

- Patients with recent exacerbations of chronic lung disease

A review of a large American-based airline over 90 days in 1991 identified 233 patients that were required by the airline to have a medical evaluation (24). Of these, 85% required in-flight oxygen. Fifty-two patients (22%) had been discharged from an acute care hospital within the two weeks

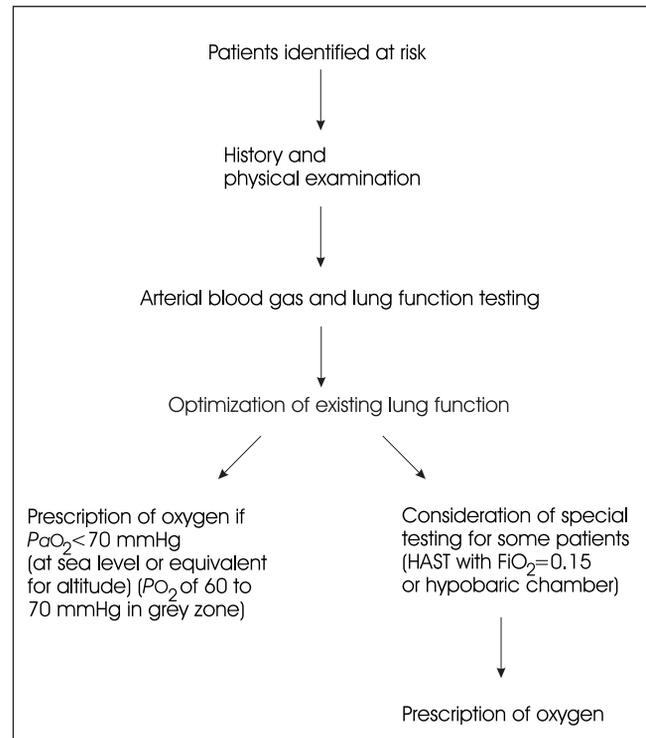


Figure 1) Assessment of patients who have been identified as potentially hypoxemic during air travel. FiO_2 Fraction of inspired oxygen; HAST Hypoxia-altitude simulation test

before flying and had a disproportionately higher incidence of in-flight difficulties than the remaining patients.

- Patients with other chronic conditions that may be aggravated by hypoxemia such as cerebrovascular disease, coronary artery disease, or chronic cardiac failure.

Preflight evaluation: For patients who are identified as being at increased risk, the preflight evaluation should include a history and physical examination, measurement of arterial blood gases, lung function testing and special testing in selected cases (Figure 1).

- Clinical evaluation

The clinical history and examination provide the basic information that may lead to a recognition of risk factors if already not known, as well as any recent change in the status of an already known condition. A history of good exercise tolerance and recent uncomplicated air travel intuitively suggests a low risk for in-flight complications while a previous history of in-flight symptoms should raise the index of suspicion.

- Arterial blood gas measurements

Ground level arterial blood gases provide the best clinical predictor of in-flight blood oxygen tension. They have their best predictive value when measured as close to the travel date as possible (4). Although commercial aircraft aim to pressurize their cabins to an equivalent of 1800 m above sea level, available data suggest that this can vary (3) and preparations for a worst case scenario of 2400 m should be made. This corresponds to an approximate barometric pressure of

565 mmHg; normal subjects will have a drop in PaO_2 from 100 to 59 mmHg when moving from sea level to this altitude assuming normocapnia. However, the usual compensatory response is hyperventilation, which causes some increase in the PaO_2 . For practical purposes, patients with a PaO_2 of greater than 70 mmHg at sea level or equivalent for their altitude are unlikely to have difficulties (4,5,17). The clinical application of predictive equations based on ground level PaO_2 and anticipated flying altitude (1,4,29) has already been discussed.

- Lung function testing

Objective measurements provided by pulmonary function testing provide an indicator of lung function and may identify patients who require more detailed evaluation. They may also be a general predictor of oxygenation (2) and provide a basis on which to optimize lung function before travel.

- Special testing

For selected patients who are at high risk or who have had previous complications during air travel, objective evaluation during simulated conditions of air travel may help assess the ability to respond physiologically, the symptoms that may be experienced and the results of oxygen supplementation. There are two approaches to laboratory testing: use of a hypobaric chamber and administration of hypoxic gas mixtures, also known as a hypoxia-altitude simulation test (HAST) (4,13,17). Use of a hypobaric chamber is limited to a few laboratories, while the inhalation of a hypoxic gas mixture with a fraction of inspired oxygen (FiO_2) of 0.15 is a practical method that can be carried out in most pulmonary function laboratories. Coupled with simultaneous measurements of either oxygen saturations by pulse oximetry or arterial blood gases (as well as continuous electrocardiogram and physician monitoring), the effects of hypoxemia can be assessed, and, at the same time, supplemental oxygen requirements can be titrated. Novel approaches for carrying out a HAST test have been described and include a technique using a venturi mask with nitrogen as a source gas to lower oxygen tension (7) and lowering ambient oxygen tension in a sealed body plethysmograph (8). Ultimately, the most practical approach might be the use of increasingly affordable and portable pulse oximeters with which oxygen can be titrated in-flight by the patient or a travelling companion (9).

Recommendations for patients: In advising a patient with chronic respiratory disease who wishes to travel by commercial airline, the physician must use a combination of clinical judgement and the available data. In summary, a general approach for assessing the patient for air travel includes the following (Figure 1):

- Clinical assessment to determine risk factors and degree of impairment;
- Measurement of arterial blood gases and lung function as close as possible to the travel date;
- Optimization of the patient's existing lung function;
- Estimation of in-flight PaO_2 and prescription for supplemental oxygen if required. In assessing the

need for oxygen therapy, the goal should be to maintain a minimum PaO_2 of 50 to 55 mmHg during the flight. Patients with a sea level PaO_2 of less than 70 mmHg are at increased risk for hypoxemia. The subgroup of these with a PaO_2 between 60 and 70 mmHg are in a grey zone depending on their estimated ability to compensate by hyperventilation. For those in whom hypoxemia is deemed probable, supplemental oxygen should be recommended. For patients who do not ordinarily require supplemental oxygen at ground level, the empiric addition of 2 L/min should adequately correct potential hypoxemia (7,8,17). For those on supplemental oxygen at ground level, an increase in the flow rate by 1 to 3 L/min is recommended. For those in whom there is uncertainty, a hypoxic gas study (eg, HAST) using an FiO_2 of 0.15 in the pulmonary laboratory is recommended.

PLANNING FOR AIR TRAVEL

In addition, there is advice regarding the logistics of air travel that the physician may be able to provide. For example, a well planned itinerary is important to minimize layovers at other airports, and direct flights should be used whenever possible. The need for a travelling companion should be considered. The patient should request a seat close to the lavatory to minimize exertion and difficulty with equipment in-flight. Patients may be responsible for supplying their own oxygen during layovers and at their destination, and must plan ahead by contacting their respiratory supply company. Patients should avoid overeating, maintain adequate hydration, ensure that they are well rested and avoid alcohol. Smoking flights should also be avoided; some overseas carriers still permit smoking in-flight. The costs associated with oxygen supplementation, airline arrangements and vendor supplies must also be considered in advance, and extra time must be given to make reservations and notify the airline of the intention to travel.

ROLE OF THE AIRLINES

Air carriers have recognized and accepted that in-flight oxygen therapy is both manageable and safe. However, many deficiencies and issues remain surrounding the use of in-flight oxygen, and at present, each airline has its own policy regarding the use of oxygen in-flight. Most airlines require advance booking and assessment by a qualified physician and consideration of individual cases by its own medical department. Most airlines prefer to use their own in-flight oxygen systems consisting of either D type cylinders or oxygen concentrators with a nonbreathing mask at set flow rates of either 2 or 4 L/min. The cost of this extra service varies considerably from airline to airline. Carriers that allow passengers to use their own equipment usually accept only the D type cylinder because of its manageable size.

At present, there is no uniform Canadian policy regarding oxygen use in commercial aircraft. However, beginning in 1995, the Accessible Transportation Directorate of the fed-

eral Canadian Transportation Agency held a series of meetings and consultations with representatives of the airline industry, respiratory equipment suppliers, patient groups and other interested parties, with the objective of developing a uniform national policy for the use of medical oxygen on commercial airlights. This policy will include agreement on standardized procedures and equipment that will be acceptable for travel. The present goal of the commercial airline industry is to transfer the responsibility for the equipment and oxygen back to the traveller. A number of issues of concern remain to be addressed including integrity of traveller-owned oxygen cylinders, mechanisms of securing the equipment

in-flight and ensuring that there is appropriate calculation of oxygen supplies for the trip, ground time and unexpected delays. While the goal is to make air travel for the oxygen user easier and the process simpler, there will be increased responsibility for the patient, physician and respiratory therapist to make careful plans for each traveller. Resolution of these issues will take time but should lead to the development of a consistent national policy.

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