Hypoxia During Air Travel in Adults With Pulmonary Disease

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ABSTRACT: At the present time, commercial aircraft cabins are required to be pressurized to the equivalent of 8,000 feet or less. Although in-flight medical emergencies are infrequent, some adults with pulmonary disease may experience significant physiological stress, exacerbation of their underlying illness, and severe hypoxemia during air travel. A careful preflight medical evaluation is essential to determine which patients with pulmonary disease can fly safely, which patients require supplemental oxygen, and which patients should not fly at all. All adults with pulmonary disease who have a preflight arterial oxygen tension of less than 70 mm Hg or a preflight pulse oximetry saturation of less than 92% should receive supplemental oxygen during air travel. The hypoxia altitude simulation test and the 6-minute walk test are useful when additional evaluation for supplemental in-flight oxygen is needed. Patients with an unstable condition, an acute exacerbation of their pulmonary disease, severe pulmonary hypertension (Class III and Class IV), or an active pneumothorax should not fly.
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More than 1 billion people throughout the world travel on commercial aircraft each year.[1–4] The number of airline passengers has been increasing in recent years and, as the population ages, a greater number of elderly individuals with chronic medical disorders are expected to fly.[5,6] For most passengers, commercial air travel poses no significant health risk.[1–3,5,7–9] However, some passengers with pulmonary disease may experience significant physiological stress, exacerbation of their underlying illness, and significant hypoxemia during flight.[10–20] For physicians to properly evaluate and advise such patients before air travel, they must have an understanding of the physiological stresses of air travel, the effect of these stresses on pulmonary disorders that are susceptible to in-flight exacerbation, and knowledge of specific guidelines for the prevention of severe hypoxemia and exacerbation of their underlying disorders during flight.[1,2,21,22]

It is important to note that infants and children with pulmonary disease may have different physiological responses during air travel than those experienced by adults.[23–27] Therefore, this article will only address air travel considerations for adults with commonly encountered pulmonary diseases.

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The Physiological Stresses of Air Travel

As an aircraft ascends to progressively higher altitudes, the air density of the atmosphere decreases exponentially. This, in turn, results in an exponential decrease in both barometric pressure and the partial pressure of atmospheric oxygen (PiO_2).[28] Most commercial aircraft fly at cruising altitudes between 25,000 and 45,000 feet. To maintain PiO_2 and the partial pressure of arterial oxygen (PaO_2) at safe levels during flight, commercial aircraft cabins are pressurized.[29,30]

There are differences in the cabin pressures of different types of aircraft at typical cruising altitudes.[31,32] In a study conducted on 240 regularly scheduled commercial flights, the measured cabin altitude was usually between 5,000 and 8,000 feet, with a mean of 6,214 feet.[33] At these cabin altitudes, PiO_2 should be between 122 and 108 mm Hg. Thus, the PiO_2 in commercial aircraft cabins is significantly lower than the sea level PiO_2 of 149 mm Hg. This, in turn, will result in a decrease in both PaO_2 and the oxygen saturation of hemoglobin (SaO_2) during air travel.[34,35]

In normal individuals, the decrease in PaO_2 during air travel will stimulate carotid body chemoreceptors and cause a reflex increase in minute ventilation. The increase in minute ventilation is primarily caused by an increase in tidal volume rather than an increase in respiratory rate.[1,3,36] There is considerable individual variation in the ventilatory response to hypoxia in humans.[37,38] Therefore, different individuals will increase their minute ventilation to different degrees during air travel. In general, the greater the hypoxic ventilatory response, the greater the PaO_2 during air travel. At aircraft cabin altitudes between 5,000 and 8,000 feet, it is estimated that the PaO_2 in normal, healthy individuals should be between 75 and 53 mm Hg, respectively, depending on the exact cabin pressure, baseline PaO_2, age, and the individual hypoxic ventilatory response.[1,2] The oxygen saturation of hemoglobin measured by pulse oximetry (SpO_2) is expected to be between 85% and 95% in this range of cabin altitudes. In normal, healthy individuals, the change in SaO_2 during air travel occurs on the flat portion of the oxyhemoglobin dissociation curve, so that large changes in PaO_2 will produce relatively modest changes in SaO_2.

Although the hypoxic ventilatory response is the most important compensatory response to the hypobaric hypoxia of the aircraft cabin environment, several other physiological responses occur as well. There is an increase in heart rate, an increase in cardiac output, and vasoconstriction of small pulmonary arteries and arterioles. As with the hypoxic ventilatory response, there is considerable individual variability in the magnitude of hypoxia-induced pulmonary vasoconstriction.[39] In healthy individuals, the vasoconstriction redistributes pulmonary blood flow to the apical regions of the lung, which are poorly perfused at sea level. This may reduce ventilation-perfusion mismatching, which could help to maintain the PaO_2 at an acceptable level during air travel.[3,40] However, individuals with pulmonary disease may have poorly ventilated areas of lung or pulmonary hypertension, both of which could contribute to a severe decline of PaO_2 with hypoxia-induced pulmonary vasoconstriction.

At the present time, United States federal regulations require that all aircraft cabins be pressurized to 565 mm Hg or greater at maximum altitude. This is equivalent to a cabin altitude of 8,000 feet or less.[41] At a cabin altitude of 8,000 feet, the PiO_2 is 108 mm Hg. In healthy individuals, the PaO_2 at a cabin altitude of 8,000 feet should be in the range of 53 to 64 mm Hg, depending on the baseline PaO_2, age and the individual hypoxic ventilatory response.[2] The SpO_2 of healthy individuals at 8,000 feet should be in the range of 85% to 91%.[2] One study showed a 4.4% decrease in mean SpO_2 among normal individuals going from ground altitude to an altitude of 8,000 feet in a hypobaric chamber.[42]

Pressurized aircraft cabins provide a safe and comfortable environment for most passengers.[20,42] However, as previously mentioned, the hypobaric hypoxia of the cabin environment can cause physiological decompensation and a severe decrease in PaO_2 during air travel in some individuals with pulmonary disorders.[10,11,15,16,18,22,43–47] The most important factors in determining the fitness of individuals with pulmonary disorders to fly are the baseline PaO_2 at ground altitude; the functional severity of the disorder; the extent of any impairment in gas exchange; the degree of reversibility of the disorder; and the pulmonary and respiratory muscle reserve to sustain an increase in minute ventilation as a compensatory response to hypoxia. The systematic evaluation of these factors can help the physician determine which patients can fly safely, which patients require in-flight supplemental oxygen and which patients should not fly at all.[16]

The Preflight Medical Evaluation

The utility of a careful preflight medical evaluation for individuals with cardiopulmonary disorders has been demonstrated in several studies.[43,48,49] The Aerospace Medical Association and the British Thoracic Society have published comprehensive guidelines for the evaluation and management of individuals before air travel.[1,2] Although there are some differences in these guidelines, they both address the importance of a preflight medical evaluation, the estimation of in-flight PaO_2, assessment of the need for supplemental oxygen during air travel and contraindications for air travel in various pulmonary disorders.

The Baseline Medical Evaluation

All individuals with pulmonary disease should have a thorough history and physical examination, as well as the following studies, before air travel: spirometry, arterial blood gasses, SpO_2, electrocardiogram for the detection of ischemic changes and dysrhythmias and the measurement of hemoglobin concentration. Patients with chronic obstructive lung disease (COPD) should have maximum voluntary ventilation (MVV) measured in conjunction with spirometry, if not routinely performed. Individuals with restrictive or interstitial lung disease should have diffusion capacity for carbon monoxide (DLCO) measured. The results of these tests are useful in estimating the patient's in-flight PaO_2 from disease-specific regression equations and for assessing the need of the patient to receive supplemental oxygen during air travel.

Fifty-Yard and 6-Minute Walk Tests

A 50-yard walk test or 6-minute walk test can be very helpful in the evaluation of some patients with pulmonary disease.[1,2] Although neither has been validated in controlled studies for the preflight evaluation of patients with pulmonary disease, it is generally believed that the ability to increase minute ventilation and cardiac output in response to exercise is a simple, reliable and practical way of assessing the cardiopulmonary reserve that such patients will need to meet the physiological demands of the hypoxemia they will experience during air travel.[2] Although the 50-yard walk test has tra-