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Assessing Patients for Air Travel

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Advising patients before air travel is a frequently overlooked, but important, role of the physician, particularly primary care providers and pulmonary specialists. Although physiologic changes occur in all individuals during air travel, those with underlying pulmonary disease are at increased risk of serious complications and require a specific approach to risk stratification. We discuss the available tools for assessment of preflight risk and strategies to minimize potential harm. We also present a case discussion to illustrate our approach to assessing patients for air travel and discuss the specific conditions that should prompt a more thorough preflight workup.

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Although flight is one of the safest transportation modes,[1] it still poses real risks to travelers, particularly those with pulmonary disease. Respiratory complaints are the second most frequent type of medical emergency encountered during a flight, after syncope or presyncope.[2] Unfortunately, many providers are not sufficiently aware of the risks of air travel to be comfortable counseling patients prior to airplane travel.[3] This review will address which patients need preflight screening, which patients should be advised against air travel, and how to mitigate the risks of flight for those with underlying pulmonary disease.

The Flight Environment

Without cabin pressurization, passengers would be exposed to conditions of severe hypoxia, because the P_{O_2} at cruising altitude (up to 45,000 feet)[4] is approximately one-sixth the value at sea level.[5] Cabins are pressurized to an equivalent of no higher than 8000 feet, which is equivalent to an inspired fraction of oxygen of 15.1% at sea level.[6] Cabin pressure in private aircraft is more variable, ranging from entirely unpressurized to sea level equivalent; a full discussion of the risks of noncommercial flights is outside the scope of this review.

Although all air travelers are exposed to reduced oxygen-tension levels during flight, those with preexisting lung disease are most susceptible to complications. Patients with limited ability to extract oxygen or those with vulnerability to myocardial hypoxemia may experience respiratory failure, cardiac ischemia, or even death during flight.

In addition to hypobaric hypoxia (reduced atmospheric pressure due to altitude, resulting in lower amounts of available oxygen), passengers are also exposed to cramped conditions with limited ambulation. Humidity levels are quite low (9%-28%),

ABBREVIATIONS: HAST = high-altitude simulation test; PFT = pulmonary function testing

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TABLE 1] Methods of Predicting In-Flight Hypoxemia

Method	Pros	Cons
Resting oxygen assessment		
Pulse oximetry	Noninvasive, inexpensive, accessible	Single point value may miss significant hypoxemia with exertion
Arterial blood gas	Inexpensive	Uncomfortable
Exercise testing		
6-Minute Walk	Minimal equipment required, widely used measurement in other pulmonary disease	Poor ability to predict inflight hypoxemia
50-Meter Walk	Assesses patient during exercise, not just at rest	Poor ability to predict inflight hypoxemia
Cardiopulmonary exercise test	Provides thorough evaluation of cardiopulmonary system	Time consuming, limited availability, expensive
Pulmonary function testing		
Spirometry, lung volumes, and diffusion capacity	Widely available, gives additional information on pulmonary disease	Poor ability to predict inflight hypoxemia
Predictive equations		
Calculation from point oxygen saturation determined by pulse oximetry or oxygen saturation	Inexpensive, quick, simple to use	Lack of agreement between equations, poor predictive ability
Altitude simulation		
Hypoxic challenge test	Good ability to predict inflight hypoxemia	Time consuming, may not be readily available at all centers
Hypobaric chamber	Most closely mimics inflight environment	Very limited clinical availability, primarily used for research, expensive, time consuming

which promotes increased insensible fluid loss and dehydration. These factors predispose passengers to VTE that compounds any hypoxia that may develop secondary to conditions of low oxygen tension.

Screening

History and Physical Examination

Patients who are planning air travel, at minimum, should undergo a history examination, a physical examination, and oxygen saturation assessment.[6] Because many patients are unaware of the need for screening; providers are encouraged to ask patients routinely about any upcoming travel. Medical history taking should address comorbidities, history of oxygen use, prior air travel, and any symptoms of chest pain, dyspnea, or cough. Physical examination should focus on the cardiopulmonary examination; any abnormalities that are identified should be investigated prior to planned travel.

Of course, medical evaluation on the day of travel is not generally feasible; patients should be advised to contact their physician if they experience new respiratory symptoms after evaluation. Providers should then reassess the patient's status and fitness for flight. If patients are experiencing an exacerbation of their underlying pulmonary disease or symptoms suspicious for a newly developing illness, travel should be deferred.

During the examination, the provider's goals should be to determine whether patients are sufficiently stable to fly and if they need supplemental oxygen during flight. In general, patients with active exacerbations of their underlying pulmonary disease, patients with unstable angina, and patients who would require more oxygen than can be supplied during flight should be instructed to find alternative methods of travel or to defer the trip. Additional information on disease-specific absolute and relative contraindications to flight are specified later.

Resting Pulse Oximetry

Our current practice is to obtain a measurement of arterial oxygenation for every patient, generally with pulse oximetry. Values >95% on room air suggest that inflight hypoxemia is unlikely and that further evaluation is likely not necessary. Patients with saturations <92% on room air at rest should receive supplemental oxygen inflight, because they are at high risk of hypoxemia at altitude. Values between 92% and 95% should prompt further evaluation, particularly in the setting of known risk factors for inflight hypoxemia. Although data for this approach are somewhat limited, they are consistent with other recommended practices.[7] Table 1 provides additional details that compare resting pulse oximetry to other methods of predicting inflight hypoxemia.

Arterial Blood Gas

Arterial blood gas analysis on room air can be obtained if pulse oximetry is thought to be unreliable or is unobtainable (despite use of alternative locations of pulse oximetry probe placement [eg, forehead or ear lobe]). Evidence of chronic CO_2 retention should prompt further evaluation and consideration of intervention ideally prior to travel. Less consensus exists on the appropriate $Pa{O_2}$ cutoff for further testing; a conservative approach would be to refer any patient with $Pa{O_2}$ of <70 mm Hg for additional testing.

High Altitude Simulation Test

If additional certainty is needed regarding possible inflight hypoxemia, the high-altitude simulation test (HAST) offers the best clinically available simulation of conditions at commercial flight cruising altitudes. During the HAST, patients breathe a mixture of gases with an inspired oxygen fraction of 15.1% via a tightly fitting mask or mouth piece for a period of 20 minutes, during which continuous ECG and pulse oximetry readings are obtained, with pre- and postarterial blood gas sampling.[8] If the $Pa{O_2}$ remains at >55 mm Hg during the test, patients are considered at low risk of hypoxemia during commercial air travel.

Although the HAST does not replicate inflight conditions perfectly (it uses normobaric hypoxia, rather than hypobaric hypoxia), results correlate well with hypobaric chamber testing (the gold standard for predicting hypoxemia at altitude, although clinically impractical).[9,10] HAST testing also predicts inflight hypoxemia relatively well in otherwise healthy individuals.[11]

Additional Testing Considerations

Pulmonary function testing (PFT) is not specifically indicated as part of the preflight workup. For patients with known pulmonary disease (specifically, COPD, interstitial lung disease, and cystic fibrosis), other authors have suggested that PFTs may be used in an algorithmic approach to determining the need for inflight oxygen.[12-14] Although PFTs clearly provide important information in the management of these chronic diseases, our practice has been to recommend HAST if there is any concern for inflight hypoxemia, rather than relying on extrapolation from PFTs.

Exercise testing (6-minute walk test, 50-meter walk test, or cardiopulmonary exercise testing) is similarly beneficial as part of chronic lung disease evaluation but does not predict consistently the degree of hypoxemia that patients will experience inflight.[15] Although very poor performance on cardiopulmonary exercise testing or 6-minute walk testing likely indicates a risk of inflight hypoxemia,[12,16,17] HAST is a more reliable method of assessing this risk (Table 1).

A variety of predictive equations have been proposed for anticipating which patients will require supplemental oxygen during air travel. A benefit of these equations is simplicity and ease of use during an office visit. Unfortunately, these equations consistently have poor predictive value, and there is little consensus on which equation to use.[18,19] Our practice has been to avoid the use of equations in assessing patients for the need for supplemental oxygen during air travel and to rely on HAST in borderline cases.

Inflight Oxygen

If it is determined that a patient requires supplemental oxygen inflight, options are generally limited to either the patient's own portable oxygen concentrator or oxygen supplied by the airline. Use of the concentrator has the benefit of being titratable and being able to travel with the person during ambulation. However, depending on the length of the flight, passengers may either need to bring supplemental batteries (with care taken to ensure that these are approved for inflight use) or have the ability to charge the device during flight. Using the airline's oxygen supply (generally available at a fixed 2 or 4 L/min) avoids the difficulty of supplemental power but does not permit oxygen use after arrival. Use of a patient's own liquid oxygen cylinder is not permitted generally. Providers should be aware that inflight oxygen use generally requires airline advance notification, a note from a physician, and potentially extra fees.[20,21]

If patients who are on long-term supplemental oxygen have not completed a HAST, our general practice is to increase their oxygen prescription by 2 L/min during flight. This is a relatively imprecise approach, based primarily on expert consensus.[7] HAST offers a significant advantage in better quantifying inflight oxygen needs. Portable oxygen concentrators can reach a maximum oxygen flow rate of 6 L/min (some devices have a lower maximum of 3 L/min), and airlines generally do not offer >4 L/min of inflight oxygen. If patients require higher flow rates to maintain adequate saturations during flight, we recommend against air travel.

Other Respiratory Equipment

Patients who use metered-dose inhalers should be instructed to bring these in the passenger cabin during flight. Although technically allowed by the Transportation Security Agency in the United States (with liquid medications exempt from the volume restrictions imposed on other fluids), nebulizers are difficult to use in flight and may disturb other passengers with their noise and aerosol distribution.

Patients with sleep apnea should be encouraged to take their CPAP or BIPAP in their carry-on luggage during travel. Whether to recommend inflight use of nocturnal positive pressure ventilation is somewhat controversial. On the one hand, patients with sleep apnea are at higher risk of hypoxemia during flight, compared with those who do not have sleep apnea.[22] Also, CPAP or BiPAP use is permitted by the Transportation Security Agency,[23] and the decreases in machine size over the past decades have made use during air travel feasible. However, carrier policies regarding CPAP or BiPAP use are variable; a recent case series of patient practices showed that 0% of CPAP users used their machine on an overnight flight (despite 50% of them sleeping during the flight).[24,25]

Ventilator-dependent patients are at significant risk of decompensation during flight[26] and require a medical escort. Advance arrangements with the flight carrier should be made, and consideration should be given (when possible) to the use of other forms of transportation.

Risk of VTE

Air travel can increase the risk of VTE, because passengers remain stationary for long periods with increased fluid loss due to low humidity and reduced access to fluids. Although the overall risk of pulmonary thromboembolism after a flight is low (0.38 incidence per one million international flight passengers, in one report), risk increases with the duration of flight and preexisting risk factors.[27] Compression stockings may reduce the risk of VTE in high-risk patients during flight and may be a reasonable recommendation.[28] Providers occasionally recommend prophylactic dosing with aspirin to prevent VTE; however, to our knowledge this practice is not evidence-based.

Disease Specific Considerations

COPD: Risk assessment for air travel in patients with COPD should follow the pattern described earlier, with history examination, physical examination, and initial screening with pulse oximetry. In patients with COPD with resting saturations between 92% and 95%, HAST is a good screening tool for inflight hypoxemia.[29] PFTs may be obtained for other reasons but should not be used to either rule-in or rule-out the need for supplemental oxygen during flight. Regarding algorithm-based assessments, which may include 6-minute walk testing, cardiopulmonary exercise testing, arterial blood gas and/or PFT data, there is some evidence that this approach can be used with success in patients with COPD.[12,16] However, if HAST is available, it is a better tool for preflight screening, given that it more directly measures the variable of interest (ie, response to hypoxic conditions).

Interstitial Lung Disease and Cystic Lung Disease: Patients with diffuse parenchymal lung disease are also at risk of hypoxemia at altitude and should be screened as described earlier. In addition, recent data published by Barratt et al[13] suggest that an algorithm-based approach (based on total lung capacity and P_{AO_2}) for referral to HAST may be warranted in patients with interstitial lung disease. In this group, resting pulse oximetry was a less reliable predictor of performance on HAST (27.8% with a resting saturation ≥96% did not meet HAST standards).

Patients with a cystic component to their lung disease should also be advised of the risk of inflight pneumothorax. They should be counseled regarding symptoms of pneumothorax development and the need for urgent medical treatment.

Pulmonary Hypertension: Although fewer data are available on the impact of air travel on patients with pulmonary hypertension, one small case series showed that hypoxemia at altitude is common for these individuals (roughly one-quarter of patients with pulmonary hypertension) and worsened by walking and

TABLE 2] Disease-Specific Considerations in Preflight Screening

Condition	Recommended Testing
For any patient	Resting oxygen saturation <92% = supplemental inflight oxygen
	Resting oxygen saturation 92%-95% = HAST
Additional disease specific testing	
COPD	No additional disease specific preflight screening recommended, unless resting oxygen saturation is <95%.
Interstitial lung disease and cystic lung disease	Consider referring patients for HAST even if no resting hypoxemia, particularly in severe disease
	Counsel patients of the risk of inflight pneumothorax
Pulmonary hypertension	Consider referral for HAST in severe disease, independent of baseline saturation
Neuromuscular disease	HAST for any patient with severe disease (FEV_1 <49% predicted)
Sleep-disordered breathing	Consider HAST, particularly for patients who require nocturnal ventilation
	Ensure accessibility to positive pressure devices during overnight travel
Contagious disease	Defer travel until deemed noninfectious by primary physician
Pneumothorax	Chest imaging prior to flight to ensure resolution of pneumothorax for at least 14 days

HAST = high altitude simulation test.

longer flight duration.[30] Results of HAST in patients with pulmonary hypertension are similar to those of patients with other chronic respiratory disease; one cohort of 36 patients reported that 28% required supplemental oxygen.[31]

Neuromuscular Disease and Chest Wall Deformity: Patients with neuromuscular disease or chest wall deformity are at risk of inflight hypoxemia because of their propensity toward hypoventilation. This is another subgroup of patients who may benefit from more frequent referral for HAST. A case series of patients with neuromuscular disease or kyphoscoliosis found that, regardless of baseline oxygen saturation, many (15 of 19 patients) met criteria for supplemental oxygen during flight based on HAST results.[32] As such, we recommend consideration for referral to HAST for any patient with neuromuscular disease or chest wall deformity who also has severe restrictive disease on PFTs (based on American Thoracic Society criteria for grading of restrictive lung disease severity, with FEV_1 <49% predicted).[33]

Sleep Disordered Breathing: Little consensus exists on the recommended preflight evaluation of patients with sleep-disordered breathing, in part due to the heterogeneity of these patients. Small case series have suggested that rates of inflight hypoxemia in this group may be significant, even in the presence of resting oxygen saturation >95% (estimates range from 6% to 50%, in series of noninvasive ventilation users).[34] HAST testing therefore should be considered, particularly in patients with severe nocturnal hypoventilation.

Contagious Disease: Viral Infection: Since the advent of the coronavirus disease 2019, individuals increasingly have become aware of the risk of airborne or droplet-based disease transmission during air travel. Any patient with suspected or confirmed contagious infection should be advised to avoid commercial flight until deemed noninfectious by their managing physician. Recent Centers for Disease Control guidelines have recommended considering patients noninfectious 10 days after symptom onset (as long as fever has resolved for 24 hours without the use of antipyretics) in the case of mild-to-moderate disease or up to 20 days in patients with severe illness or immunocompromise.[35]

Regarding the potential for transmission of other viral illnesses during air travel, risks are reduced (although not eliminated) by current systems for cabin air exchange and filtration. Although systematic studies are very limited, available data suggest that approximately 20% of passengers report new upper respiratory infection symptoms within 1 week of flight.[36]

TB: Patients with pulmonary TB should be counseled to avoid all air travel until they have three negative sputa for acid fast bacilli. This is particularly crucial in cases of drug-resistant TB because the confined space of the commercial aircraft cabin provides ample opportunity for the bacillus to be transmitted from person to person.[7]

Pneumothorax: Because of the lower pressure at altitude, patients with pneumothorax are at risk for the expansion of the intrathoracic air pocket, resulting in respiratory distress and/or hypoxemia. Currently, the British Thoracic Society recommends waiting 2 weeks after pneumothorax resolution on chest radiograph to fly (whether the pneumothorax was managed conservatively, with a drain, or with pleurodesis).[7] Although use of a one-way valved pleural drain is possible, concerns about follow up and care at the destination site limit the practicality of this approach. Patients with chronic pneumothorax present a challenge to providers; in a case series of two patients with chronic pneumothorax, Currie et al[37] described extensive testing, which included HAST and hypobaric chamber testing and resulted in an assessment that both patients were fit to fly. One of the two patients then went on to complete multiple transatlantic flights without incident.

Other Considerations: Please see Table 2 for a summary of disease specific recommendations for preflight assessment. Patients with any recent surgery, particularly those that involve the cranial vault or thorax, are at risk of inflight expansion of postsurgical air pockets. Any travel plans should be discussed with the surgeon. Severe decompression sickness ("bends") generally is considered a contraindication to flight, again, due to the risk of further expansion of trapped gas pockets. Controversy exists regarding milder cases, with some experts recommending avoidance of any air travel and others suggesting that it may be safe in cases in which patients require transportation to more advanced medical care.[38] Patients with severe anemia or hemoglobinopathies are at increased risk of inflight tissue hypoxia and, in the case of sickle cell disease, may be at increased risk of sickling.[39]

Case: A 32-year-old woman with cystic fibrosis and 2 L/min of oxygen presents for routine pulmonary follow up. Her last admission was 18 months ago, and she is compliant with her airway clearance regimen. She lives in California and is planning to travel to Florida for a family reunion. She has not flown since starting oxygen 2 years ago. Vital signs are notable for oxygen saturation level determined by pulse oximetry of 96% on 2 L/min of oxygen, and examination reveals bilateral rhonchi and scattered wheezes, which clear with cough. How would you advise this patient regarding her upcoming air travel?

Discussion: We would recommend that she increase her oxygen during flight to 4 L/min. If desired, a HAST could also be ordered to better quantify the amount of oxygen that she requires during flight. We would also advise her to defer travel if she was having symptoms of an exacerbation. She should bring her metered-dose inhalers, nebulizer, vest, and all prescription medication in her carry-on luggage to avoid losing them in transit and to allow the use of her inhalers inflight if needed. There is some increased risk of pneumothorax during flight, and she should be advised to seek medical care on arrival to her destination if she experiences worsening dyspnea or chest pain. Given her significant pulmonary disease, we would also suggest the alternative of overland travel (via train or car) as a way of avoiding the risks of air travel entirely.

Summary, Recommendations, and Resources to Improve Communication

Air travel carries the risk of complications, particularly in patients with a history of lung disease. Patients with risk factors for inflight hypoxemia should undergo history examination, physical examination, and pulse oximetry. Any patient with a resting oxygen saturation level determined by pulse oximetry of <92% should receive inflight supplemental oxygen. 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 HAST before air travel.

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