

Aerospace Medicine: Part 4

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Abstract

CLINICAL PRE-FLIGHT ASSESSMENT IN AEROSPACE MEDICINE

There are several procedures that used to assess whether patients are fit to air travel. These procedures are the following:

1) THE 50 METERS WALK (144,145)

The ability to walk 50 meters without distress is traditionally favored by airline medical departments because of its simplicity, but it is often the only subject of enquiry and is not verified. There is no evidence validating this test. Although this may seem a crude assessment, the ability to increase minute ventilation and cardiac output in response to an exercise load is a good test of cardiorespiratory reserve. It is also a common sense approach to simulating the stress of the additional hypoxemia that patients will experience at rest during a flight.

The walk test used should be that in use in the laboratory where the assessment is being performed. Failure to complete the task (in terms of distance or time) or moderate to severe respiratory distress (recorded on a visual analogue scale) will alert the physician and the patient to the possible need for in-flight O₂. Walk tests are obviously not suitable for those with lower limb arthritis or neuromuscular weakness.

2) PREDICTING HYPOXEMIA FROM EQUATIONS

Some centers use one of several equations to predict PaO₂ or SaO₂ from measurements at SL. The equations have been derived almost exclusively from patients with COPD who have had measurements of PaO₂ in a hypobaric chamber, or before and during exposure to simulated altitude while breathing 15% inspired O₂ from a reservoir bag. These equations use pulmonary function variables (FEV₁/FVC) and/or arterial PaO₂ at SL to predict in-flight PaO₂. Most take a worst-case scenario and assume that the in-flight

cabin pressure is equivalent to 2,400 meters. The predictions are reliable enough to establish upper and lower thresholds for "no in-flight O₂ required" (SaO₂ >95%) or "in-flight O₂ needed" (SaO₂ <92%). (146,147)

The nomogram provides a graphic method for estimating PaO₂ during air travel in patients with COPD using PaO₂ at SL and FEV₁% of predicted based on a regression equation. (7) Estimates close to 50 mm Hg for PaO₂ (e.g., ±3 mm Hg) during flight might be considered further for hypoxic inhalation test (HIT), if available. The prediction is favored from regression equations as an initial step for most patients with COPD and reserve the HIT for selected cases. (148)

EXAMPLES OF EQUATIONS FOR PREDICTING HYPOXEMIA:

This relates PaO₂ at altitude (Alt) to PaO₂ at SL (Ground)
(146) $\text{PaO}_2 \text{ Alt (mm Hg)} = 0.410 \times \text{PaO}_2 \text{ Ground (mm Hg)} + 17.652$

This relates PaO₂ Alt to PaO₂ Ground and includes FEV₁ in liters: (146) $\text{PaO}_2 \text{ Alt} = 0.519 \times \text{PaO}_2 \text{ Ground (mm Hg)} + 11.855 \times \text{FEV}_1 \text{ (liters)} - 1.760$

This relates PaO₂ Alt to PaO₂ Ground and includes FEV₁ as % predicted: (146) $\text{PaO}_2 \text{ Alt} = 0.453 \times \text{PaO}_2 \text{ Ground (mm Hg)} + 0.386 \times (\text{FEV}_1 \% \text{ pred}) + 2.44$

This relates PaO₂ Alt to PaO₂ Ground and includes flight or altitude: (147) $\text{PaO}_2 \text{ Alt} = 22.8 - (2.74 \times \text{altitude in thousands of feet}) + 0.68 \times \text{PaO}_2 \text{ Ground (mm Hg)}$

3) HYPOXIC INHALATION TEST (HIT)

A hypoxia inhalation test can identify patients with respiratory disease, who may be at risk of developing respiratory distress during commercial air travel. The hypoxic inhalation test described by Gong et al. is therefore often used. (148) It assumes that breathing hypoxic gas mixtures at SL (normobaric hypoxia) equates to the

hypobaric hypoxia of altitude. Subjects are usually asked to breathe the hypoxic gas mixture for 20 minutes or until equilibration. Saturation is monitored throughout, and blood gas tensions measured before and on completion. (149)

There are two methods currently in use. The patient can be asked to breathe 15.1% O₂. This creates a hypoxic stress equivalent to that in aircraft cruising at 2,400 m (8000 ft). The second method can be used where high flow nitrogen is administered through a 35% ventimask. Entrained air creates a gas mixture with 16.1% O₂. Nasal prongs to determine appropriate O₂ flow rates can add supplemental O₂. (150)

Fifteen percent O₂ can be administered in several ways. Oxygen and N₂ can be mixed in the appropriate proportions in a Douglas bag or cylinders of 15% O₂ in N₂ can be bought from British Oxygen Corporation. The gas mixture can be given with a non-rebreathing valve with a mouthpiece or tight fitting face-mask. It is possible to fill a body box with 15% O₂ to provide the hypoxic environment without using a face-mask. The entrained air dilutes the N₂ producing a 14–15% O₂ mixture under experimental conditions. Using a 35% Venturi mask will yield a 15–16% O₂ mixture. (151)

A subject is usually judged to require in-flight O₂ if the PaO₂ falls <50 mm Hg or SaO₂ falls <85%. These figures appear arbitrary with no supporting evidence. Hypoxic inhalation testing is the pre-flight test of choice for patients with hypercapnia. As with equations, flight duration and cabin conditions are not reproduced. (152)

If SaO₂ was < 85% no HIT was performed and the patient was assessed as unfit for air travel. If baseline SaO₂ was > or = 85% an HIT was performed. Validation of such protocols is difficult, but the HIT may be a useful tool for predicting hypoxia during air travel in patients with chronic respiratory disease. (152)

Pulse oximetry should not substitute for ABG's measurement during HIT but does seem useful to titrate O₂ during a HIT. Limitations of pulse oximetry during acute hypoxia such as air travel include the tendency to overestimate arterial saturation and, likewise, to imply a greater PaO₂ than actually exists. (153)

4) NONSPECIFIC BRONCHIAL HYPERRESPONSIVENESS (NBHR)

Some authors favor routine testing for nonspecific bronchial hyper-responsiveness, with an agent such as methacholine, as a prerequisite for initial entry on military flight-duty

status in circumstances in which uncompromised lung function under all environmental conditions is considered essential. However, a recent study of US Army Reserve Officer Training Corps cadets raised concerns over false-positive test results when higher concentrations of methacholine are considered positive. (101)

5) LOWER BODY NEGATIVE PRESSURE (LBNP)

It has been used for decades in aerospace physiological research to investigate cardiovascular mechanisms that are associated with or underlie performance in aerospace and military environments. LBNP represents a relatively safe method for inducing highly reproducible hemodynamic responses during exposure to foot ward fluid shifts. The applications of LBNP to the study of blood pressure regulation in space flight and ground-based simulations of low gravity have provided counter-measures based on physiological mechanisms underlying the operational problems. (154)

Lower body negative pressure can be considered as an experimental substitute for the +Gz stress. In military aviation, pilots assume a near upright position and are subjected to +Gz stress. LBNP chamber has been developed in which negative pressure can be applied to the subject in the upright-seated position. The chamber can assess the tolerance of subjects likely to be exposed to high levels of +Gz stress. (155)

6) CHEST RADIOGRAPHS

Previous studies have shown low efficacy of screening chest radiographs in various populations. Also, based on data from routine chest X-ray screening of flight duty applicants, it does not appear to be justified. (102)

7) LUNG FUNCTIONS (61)

Uncompromised lung function is essential for fitness to fly. Under hypobaric conditions there is an increased risk of hypoxemia. G-forces, positive pressure breathing and anti-G maneuvers cause physical stress to the lung tissue and altered pulmonary blood flow. Breathing with pure O₂, dry cabin air and ozone can cause airway irritation. Chemically and physically irritating agents may be present. Smoke in the cockpit or inhalation of tear gas can rapidly compromise the pulmonary system in susceptible persons. Trapped gases may cause overinflation and lung rupture in rapid decompression. Applicants for military duty have to pass basic PFT's routinely.

Due to aeromedical experience the latent NBHR must be

considered. If NBHR exists there is an increased risk of later development of bronchial asthma. Under certain conditions NBHR can become symptomatic and aeromedically relevant. NBHR is recommend in the selection of personnel for duties where uncompromised lung function under all environmental conditions is essential.

OXYGEN PRESCRIPTION IN AEROSPACE MEDICINE

Application of 2 L/min continuous O₂ flow by nasal cannulae replaces most of the inspired O₂ lost in an ascent to 8000 ft. Adding 2 L to current home O₂ delivery therefore should suffice for most patients. However, in selected patients, confirmation for desired O₂ should be considered by HIT testing followed by O₂ titration. (156)

Most airlines do not permit patients to bring their own O₂ aboard but will provide O₂ on receipt of a prescription from a physician at least 48 hours before the intended flight. Most air carriers now can support nasal cannulae at discrete flow rates, typically ranging from 2 to 8 L/minute. (157)

Pulse oximeters, which have become increasingly portable and affordable, do not yet have a strongly proved role for monitoring individual patients during air travel. The significance of a single measurement in the acute altitude setting in the absence of acute illness is unclear. Physicians should avoid having patients monitor their own pulse oximetry “just in case” without a prescription for O₂ approved by the airline in advance. Portable blood gas analyzers have been developed that may become useful. (158)

INDICATIONS OF O PRESCRIPTION (156,158)

1. Ischemic heart disease in high altitude (> 8000 ft).
2. Hemodynamic instability patients.
3. Advanced emphysema (FEV1<1 liter).
4. Pulmonary fibrosis.
5. Eisenmenger's syndrome.
6. Primary pulmonary hypertension.
7. Dilated cardiomyopathy with amiodarone lung.
8. Cystic fibrosis.
9. Severe pulmonary hypertension caused by thromboemboli.

10. Already on home oxygen.

11. Long or transcontinental flights with PaO₂ <60 mmHg.

Saturation was maintained at values a minimum of 85% or above for the previous diseases by pulse oximetry, if measured, during air travel in known patients. Studies have shown that patients with serious cardiopulmonary disease must be assessed before travel and supplementary O₂ used if necessary. Patients with heart and lung disease should contact their doctors early. (156,158)

The effects of O₂ supplementation in patients with severe COPD (mean FEV₁ 31% predicted) have been investigated. Baseline PaO₂ at SL was 9.47 kPa, which fell to 6.18 kPa when exposed to an altitude of 2438 m in a hypobaric chamber. The subjects were then given supplemental O₂; 24% O₂ by Venturi mask increased PaO₂ to 8.02 kPa, 28% O₂ by Venturi mask increased PaO₂ to 8.55 kPa, and 4 l/min via nasal prongs increased PaO₂ to 10.79 kPa. This suggests that, in patients with COPD, 24% and 28% O₂ via Venturi masks (and probably 2 l/min via nasal prongs) will improve hypoxemia at 2438 m but will not fully correct it to SL values. However, O₂ given at 4 l/min via nasal prongs will produce values above SL baseline. (159)

METHOD OF OXYGEN DELIVERY

Oxygen can be supplied via a Hudson mask (patients using venturi masks or nasal cannulae can bring these with them). Aircraft oxygen delivery systems are usually limited to 2 or 4 l/min. This is probably best delivered by nasal prongs as the simple O₂ masks provided by many airlines may allow some re-breathing and worsen CO₂ retention in susceptible subjects. Using 100% O₂ at a rate of 4 l/min via nasal prongs from a cylinder will produce a PaO₂ at 2438 m (8000 ft) cabin altitude slightly higher than SL PaO₂ on air. Using 2 l/min via nasal prongs should correct the fall in O₂. (5)

The O₂ delivery systems depend upon the specific aircraft, but the supply is usually from cylinders. In some aircraft O₂ can also be tapped from the “ring main” of O₂. Regulations vary with each airline, which can decline the patient's request to travel. (160) A comparative study of arranging in-flight O₂ on commercial air carriers was performed; 76% of the 33 carriers contacted offered in-flight O₂. There was significant variation in O₂ device and liter flow availability. Flow options varied from only two flow rates (36% of carriers) to a range of 1–15 l/min (one carrier). All carriers

provided nasal cannulae, which was the only device available on 21 carriers. (161)

USE OF OXYGEN AT EXTREME ALTITUDE

At extreme altitude (8848 m) supplementary O₂ can be used to prevent severe hypoxia. Although Everest has been climbed without O₂, most climbers use supplementary O₂ above 6500 m. However, it is difficult and expensive to arrange O₂ supplies so flow rates are kept low. The O₂ is used when sleeping, normally at 12 l/min via a face- mask, and when climbing above 8000 m, normally 2-3 l/min. (8)

GUIDELINES AND RECOMMENDATIONS FOR PRE-FLIGHT ASSESSMENT FOR AIR TRAVELERS WITH PULMONARY DISEASES

A North American service offering expert assistance by radio link for in-flight medical emergencies logged 8500 calls in 2000, of which 11% were respiratory in nature. Physicians should therefore be aware of the potential effects of the flight environment in passengers with lung diseases. New evidence based guidelines from the BTS have been developed to address this problem by summarizing knowledge for adults and children with all respiratory diseases and making recommendations for assessment before traveling. (32)

The following groups should be assessed: (5)

- Severe COPD or asthma;
- Severe restrictive disease (including chest wall and respiratory muscle disease), especially with hypoxemia and/or hypercapnia; [C]
- Patients with cystic fibrosis; [C]
- History of air travel intolerance with respiratory symptoms (dyspnea, chest pain, confusion or syncope); [C]
- Co-morbidity with other conditions worsened by hypoxemia (cerebrovascular disease, coronary artery disease, heart failure); [C]
- Pulmonary tuberculosis; [C]
- Within 6 weeks of hospital discharge for acute respiratory illness; [C]
- Recent pneumothorax;
- Risk of or previous venous thromboembolism;

- Pre-existing requirement for oxygen or ventilator support. [C]

The new guidelines point out that using a combination of pulse oximetry and identification of predisposing risk factors such as abnormal spirometry can identify vulnerable patients. Those patients with resting O₂ saturation below 92% or 92-95% on air with additional risk factors are recommended to have a formal HIT to identify whether they are able to compensate for the altitude. Supplementary O₂ is recommended for those patients whose PaO₂ remains below 6.6 kPa. The in-flight PaO₂ can be estimated in several different ways as previously mentioned in pre-flight assessment. (150)

The following assessment is recommended: (5)

- History and examination with particular reference to cardiorespiratory disease, dyspnea, and previous flying experience; [C]
- Spirometric tests (in non-tuberculous patients only); [C]
- Measurement of SaO₂ by pulse oximetry. ABG's are preferred if hypercapnia is known or suspected. [C]
- In those who are screened who have resting SL oximetry between 92% and 95% with additional risk factors, HIT is recommended. [C]

Figure 1

Table (IV): Results of initial assessment

Screening result	Recommendation
SL SaO ₂ >95%	Oxygen not required [B]
SL SaO ₂ 92-95% and no risk factor *	Oxygen not required [C]
SL SaO ₂ 92-95% and additional risk factor*	Perform hypoxic challenge test with arterial or capillary measurements [B]
SL SaO ₂ <92%	In-flight oxygen [B]
Receiving supplemental O ₂ at SL	Increase the flow while at altitude [B]

*Additional risk factors: hypercapnia; FEV₁ <50% predicted; lung cancer; restrictive lung disease involving the parenchyma (fibrosis,) chest wall (kyphoscoliosis) or respiratory muscles; ventilator support; cerebrovascular or cardiac disease; within 6 weeks of discharge for an exacerbation of chronic lung or cardiac disease.

NOTES (5)

The following groups should not fly:

1. Patients with infectious tuberculosis must not travel by public air transportation until rendered non-infectious.
 2. Those with a current closed pneumothorax should avoid commercial air travel.
 3. Patients who have undergone major thoracic surgery should ideally delay flying for 6 weeks after an uncomplicated procedure. Patients should only fly if essential.
 4. Cancer per se is not a contraindication to flying. However, associated respiratory diseases should be considered in their own right.
 5. Additional precautions for all passengers:
 7. Excess alcohol should be avoided before and during the flight.
 8. Individuals not receiving oxygen should remain mobile during the flight.
 9. The risk of thromboembolic disease should initiate prophylactic measures.
 10. Patients should carry preventative and relieving inhalers in their hand luggage.
 11. Portable nebulisers may be used at the discretion of the cabin crew.
 12. Patients should check with their pharmacists whether the extreme temperature in the hold baggage compartment might adversely affect any medicine.
 13. Dry cell battery powered CPAP machines may be required by patients with obstructive sleep apnea on long haul flights.
 14. Ventilator dependent patients should inform the airline of their requirements at the time of reservation. A doctor's letter is required outlining the medical diagnosis.
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1. Logistics of air travel with oxygen: supplementary in-flight oxygen is usually prescribed at a rate of 2 l/min and should be given by nasal cannulae. For patients on oxygen at SL, the rate should only be increased while at cruising altitude.
 2. In complex circumstances patients can be referred for testing

in a hypobaric chamber. Even with in-flight oxygen, travel cannot be guaranteed to be safe

TELEMEDICINE IN PULMONARY DISEASES

INTRODUCTION

It has been a part of medicine's technological armamentarium for a number of years, and space program has been developing and applying it for care of astronauts during space flight and on space mission of long duration. Telemedicine was first used by National Aeronautics and Space Administration (NASA) in the early 1960s. Telemedicine holds the promise of real-time, interactive medical consultations with regional medical centers for physicians practicing in rural or remote areas. Also, it promises to be useful for medical consultations by emergency medical personnel at accident sites. (2)

NASA has developed a compact telemedicine instrumentation pack (TIP) for space operations. The TIP is capable of transmitting to earth a variety of clinical information, including vital signs, pulse oximetry and electrocardiogram data, and video displays from ophthalmoscopy. (162)

Terrestrial use of telemedicine has not yet been incorporated by most physicians in daily practice, as evidenced by the low volume of telemedicine consultations. The wider use of telemedicine has been dampened by controversies about quality, assurance, certification, and liability as well as by technological limitations. (163)

Over the past several years, there has been a resurgence of interest in telemedicine. The current revolution in communications technology provides an opportunity for novel approaches to management of medical illness. As economic imperatives lead to a progressive reduction in the time that health-care providers spend with their patients. (164)

Telemedicine can enable the provision of high-quality care in a pulmonary clinic setting. Evaluation of patients by telemedicine was as effective as the traditional mode. The telemedicine physician and the physician examining the patient in the traditional manner were able to elicit the same key complaints and hear the same adventitious sounds on auscultation of the lungs. (165)

THE EXAMPLES OF TELEMEDICINE UTILITY IN PULMONARY DISEASES

1) BRONCHIAL ASTHMA

The Home Asthma Telemonitoring (HAT) system aimed to help asthma patients to follow their self-care plans according to the National Asthma Education and Prevention Program (NAEPP) recommendations. This allowed early recognition of potentially dangerous situations and timely intervention. The HAT system provides reliable reciprocal exchange of all relevant information between a physician and asthma patient in home settings. Further evaluation demonstrated that lung function test results collected during home asthma telemonitoring are comparable to those collected under the supervision of trained professionals. Internet-based HAT can be successfully implemented in a group of patients without previous computer experience. HAT has a potential for improving clinical outcomes and quality of life in asthma patient. (166)

A newly developed telespirometry system consisting of a portable spirometer that transmits the lung ventilatory values by telephone from the patient's home to a remote monitoring center is used to detect early signs of asthmatic deterioration. In patients with severe asthma, the decision was made during oral communication between the patient and the operator and was based on clinical impression. Home monitoring of asthmatic patients with the telespirometry system may improve the management of the disease and the quality of life and reduce costly hospitalizations. (167)

2) COPD

Computerized, telephone-linked communication systems offer an inexpensive, widely available alternative with which patients and providers can maintain contact. Such systems may be particularly useful for providing ongoing monitoring and education of patients with chronic illnesses such as COPD. Such system can provide telephone-linked care for COPD (TLC-COPD). There is a rationale for expected improvements in disease control, quality of life, and for a reduction in acute health-care utilization. (164)

Experience in home telecare, via interactive video, has been limited to provision of ongoing support for relatively stable individuals with chronic illness. However, real time, interactive video, via an analogue video-phone, can be used to allow acutely ill patients with exacerbations of COPD at home, to obtain nursing support from a nurse located at a distant base station. (168)

3) RESPIRATORY FUNCTION TESTS

A new desktop spirometer, the Diagnosa, is a fully

integrated system, able to determine spirometry, ECG, blood pressure and body composition. Real time data can be transferred via Internet to a remote receiving center. The Diagnosa spirometer is comparable to a standard laboratory spirometer and can be used reliably for telemedicine purposes. (169)

4) PULMONARY RADIOLOGY

An interesting study compared conventional thoracic radiographs with 12-bit digitized images of the same radiographs in terms of subjective image quality and accuracy of diagnosis of subtle disease. The images were chosen for the subtlety of their findings (nodules, pneumothoraces, interstitial lung disease). Sensitivities for detecting nodules, pneumothoraces, and interstitial lung disease on digitized chest radiographs were 58%, 75%, and 90%, respectively, compared with 62%, 79%, and 92%, respectively, on the original radiographs. None of these differences was statistically significant. Digitization of radiographs for primary diagnosis by teleradiology results in a slight decrease in sensitivity for detection of subtle abnormalities, provided that the images are viewed at maximum resolution. The non-significant differences between the teleconferencing images and the original images suggest that a PC-based teleconferencing system could be useful in the diagnosis of radiological abnormalities on chest radiographs. (170)

A computer-based system can be routinely used for home reporting of nuclear medicine scans performed out of hours. Ventilation/perfusion scans can be reliably reported from computer screen images. Chest radiographs are also digitized and transferred to the home personal computer. (171)

5) PULMONARY PATHOLOGY

Internet transmission of digital images makes it possible to consult pathologists anywhere in the world. Digital camera technology has developed rapidly and a large choice of reasonably priced, user-oriented models is now available. These can be used for both macroscopic and microscopic photography with good resolution. Two pathologists at Korea University Hospital and John Hunter Hospital made Telepathology diagnoses with 95% and 97% concurrence, respectively. The current level of commercial technology yields fast, convenient and economical tools for practical telepathology diagnosis. (172)

Current Internet-based teleconferencing techniques allow a referring pathologist to transmit real-time images from a

microscope to a consultant. In a recent study, 50 randomly selected transbronchial biopsies from lung allograft recipients and 58 randomly selected endomyocardial biopsies from heart transplant patients were diagnosed by consultant pathologists using Internet-based teleconferencing methods. Consultations were completed in 5 to 15 minutes per case. Internet-based teleconferencing techniques provide effective and relatively inexpensive tools for real time telepathology consultations. (173)

Robotic telepathology is well established in the USA as a method of case referral. In a recent study of pulmonary pathology, forty cases (20 bronchoscopic and 20 surgical lung biopsy/resection specimens) were reviewed in blinded fashion by a single pathologist using robotic telepathology. This study showed that robotic telepathology is accurate for primary diagnosis in pulmonary histopathology, but modifications in both laboratory protocols and telepathology

hardware are needed to decrease the time difference between telepathology and conventional light microscopy. (174)

Telepathology systems can be used for fine needle aspiration analysis without major diagnostic errors. Their use can improve the endoscopic sampling and avoid second anesthesia when missing the lesion of request during first examination. (175)

Visual telecommunication (telepathology) was applied for expert consultation in intra-operative frozen sections and tumor classification of paraffin-embedded, poorly differentiated bronchial carcinoma. The time required for intra-operative diagnosis was 6-10 min. Telepathology can be successfully used for expert consultation of intra-operative frozen sections and panel discussions of difficult bronchial carcinoma cases. (176)

References

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