ORIGINAL ARTICLE

Air travel and chronic obstructive pulmonary disease: a new algorithm for pre-flight evaluation

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Received 2 March 2012
Accepted 7 June 2012

ABSTRACT

Background The reduced pressure in the aircraft cabin may cause significant hypoxaemia and respiratory distress in patients with chronic obstructive pulmonary disease (COPD). Simple and reliable methods for predicting the need for supplemental oxygen during air travel have been requested.

Objective To construct a pre-flight evaluation algorithm for patients with COPD.

Methods In this prospective, cross-sectional study of 100 patients with COPD referred to hypoxia-altitude simulation test (HAST), sea level pulse oximetry at rest ($SpO_{2\ SL}$) and exercise desaturation ($SpO_{2\ 6MWT}$) were used to evaluate whether the patient is fit to fly without further assessment, needs further evaluation with HAST or should receive in-flight supplemental oxygen without further evaluation. HAST was used as the reference method.

Results An algorithm was constructed using a combination of $SpO_{2\ SL}$ and $SpO_{2\ 6MWT}$. Categories for $SpO_{2\ SL}$ were >95%, 92–95% and <92%, the cut-off value for $SpO_{2\ 6MWT}$ was calculated as 84%. Arterial oxygen pressure ($PaO_{2\ HAST}$) <6.6 kPa was the criterion for recommending supplemental oxygen. This algorithm had a sensitivity of 100% and a specificity of 80% when tested prospectively on an independent sample of patients with COPD (n=50). Patients with $SpO_{2\ SL}$ >95% combined with $SpO_{2\ 6MWT}$ ≥84% may travel by air without further assessment. In-flight supplemental oxygen is recommended if $SpO_{2\ SL}$=92–95% combined with $SpO_{2\ 6MWT}$ <84% or if $SpO_{2\ SL}$ <92%. Otherwise, HAST should be performed.

Conclusions The presented algorithm is simple and appears to be a reliable tool for pre-flight evaluation of patients with COPD.

Key messages

What is the key question?

- Can pulse oximetry at rest and during exercise be used to decide whether patients with chronic obstructive pulmonary disease (COPD) should use supplemental oxygen during air travel?

What is the bottom line?

- A simple and reliable pre-flight evaluation algorithm for patients with COPD based on sea-level pulse oximetry at rest and during a 6 min walk test is presented.

Why read on?

- The pre-flight evaluation algorithm might be useful for physicians treating patients with COPD.

INTRODUCTION

The reduced atmospheric pressure in the aircraft cabin may cause severe in-flight hypoxaemia and respiratory symptoms in patients with lung disease, for example, chronic obstructive pulmonary disease (COPD).[1–9] With the growing prevalence of COPD[10] and a large proportion of patients with COPD travelling by air,[1 9] simple and practical methods for pre-flight evaluation of the patients' fitness to air travel have been requested.[1 3 11]

Current air travel statements[1 2 12] recommend supplemental oxygen when the arterial oxygen pressure (PaO_2) is expected to fall below 6.6 or 7.3 kPa (50 or 55 mm Hg). Various lung function variables, prediction equations and algorithms have been proposed to estimate in-flight PaO_2, the need for in-flight supplemental oxygen, and to select patients needing more advanced pre-flight testing, such as the hypoxia-altitude simulation test (HAST).[1 3 6 13–20] HAST is considered to be the clinical 'gold standard',[3 21] but is time consuming and not widely available. Thus, it is important to minimise the number of patients needing referral to HAST. Prediction equations, sea level PaO_2 and spirometric values alone have proven not to be reliable tools for estimating the risk of severe in-flight hypoxaemia.[1 3–5 16 22] In an algorithm published by the British Thoracic Society (BTS), sea-level oxygen saturation by pulse oximetry ($SpO_{2\ SL}$) was used as a discriminating variable,[13] and it was recently confirmed that a $SpO_{2\ SL}$<92% seems to be an appropriate cut-off value for recommending in-flight supplemental oxygen without further pre-flight evaluation.[23] For $SpO_{2\ SL}$≥92%, however, the predictive properties for detecting in-flight hypoxaemia were lower.[23] It has been shown that both exercise desaturation[15 24 25] and aerobic capacity[4 5] correlate significantly with in-flight PaO_2. Thus, it would be of interest to study if a combination of $SpO_{2\ SL}$ and standardised exercise testing could be used to minimise the number of patients needing more cumbersome pre-flight testing. Our hypothesis was that a combination of $SpO_{2\ SL}$ and oxygen desaturation during a 6 min walk test (6MWT) can be used to differentiate between patients with COPD needing or not needing supplemental oxygen during air travel, and patients who need further pre-flight evaluation with HAST.

To test this hypothesis, SpO_2 was measured in a group of patients with COPD at rest and during a 6MWT, and the results were compared with oxygen tension and saturation obtained during HAST. The primary aim of the study was to develop a simple and reliable algorithm for pre-flight evaluation of patients with COPD based on these variables. The secondary aim of the study was to evaluate if HAST can be performed with SpO_2 as a substitute for PaO_2, since use of a non-invasive HAST could make the test simpler to perform and thereby more available.

METHODS

This prospective cross-sectional study was performed at a pulmonary rehabilitation hospital in Norway. The Regional Committee for Medical Research Ethics approved the study (S-08640b), and written informed consent was obtained from the participants. The study was recorded in ClinicalTrials.gov (NCT00896584).

Construction of the algorithm

The construction of the algorithm was based on sea-level measurements of lung function, blood gases, pulse oximetry and 6MWT. For recommending in-flight oxygen, $PaO_{2\ HAST}$<6.6 kPa was chosen.[1 14 21 26] To make the algorithm practical and clinically useful, the non-invasive variables with highest correlation to $PaO_{2\ HAST}$ were analysed with receiver operating characteristics (ROC) analysis, first including all participants and second with subjects grouped according to SpO_2 >95%, 92–95% and <92%.[13] Results from the ROC analyses served as a basis for the construction of the algorithm, and thereafter all subjects were individually tested for calculation of the sensitivity and specificity of the new algorithm. Finally, the algorithm was prospectively validated on an independent sample of patients with COPD.

Subjects

One hundred and thirty-nine consecutive patients with COPD who were referred from chest physicians in southern Norway to pre-flight evaluation were invited to participate in the study. The referral criteria were moderate to very severe COPD according to the Global Initiative for Chronic Obstructive Lung Disease (GOLD),[27] previous air travel intolerance, or $SpO_{2\ SL}$ ≤95%.[1 13] The inclusion criteria were a diagnosis of moderate to very severe COPD[27] and the ability to perform a 6MWT. Exclusion criteria were unstable angina, uncontrolled hypertension, uncontrolled arrhythmia and long-term oxygen treatment. Thirty-nine patients were excluded, resulting in a study population of 100 subjects (figure 1). Sixty-nine of the participants had known comorbidities, the most frequent being systemic arterial hypertension, ischaemic heart disease and muscular-skeletal disorders. All patients used their daily medication.

Fifty additional patients with COPD who were referred to HAST with equal criteria as the study population were used to validate the algorithm.

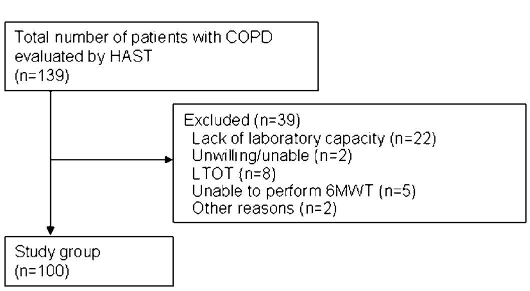

Figure 1 Flow chart describing the patient selection. COPD, chronic obstructive pulmonary disease; 6MWT, 6 min walk test; HAST, hypoxia-altitude simulation test; LTOT, long-term oxygen treatment.

Sea-level measurements and HAST

Lung function tests were performed according to standard criteria. $SpO_{2\ SL}$ was measured with pulse oximetry (Nonin 3100 Wristox or Nonin PalmSat 2500, Nonin Medical Inc, North Plymouth, Massachusetts, USA), and simultaneously an arterial blood sample was drawn from a radial artery catheter and immediately analysed (ABL800 Flex, Radiometer, Copenhagen, Denmark). Exercise-related dyspnoea was measured with the modified Medical Research Council Dyspnoea Scale (mMRC).[28]

The 6MWT was performed in accordance with standard criteria,[29] and SpO_2 and dyspnoea (Borg CR10[30]) were recorded every minute. None of the patients used supplemental oxygen during the 6MWT.

HAST was used to simulate a cabin pressure corresponding to an altitude of 2438 m above sea level (8000 ft).[6] The subjects breathed 15.1% oxygen (15.1% O_2, 84.9% N_2, Yara Praxair, Norway) from a non-diffusing gas collection bag (170 litre Douglas-bag, Hans Rudolph Inc, Shawnee, USA) through a facemask (Mirage Full Face Mask, ResMed Corp, Poway, California, USA), and arterial blood samples were taken after 15 min hypoxic exposure.[6 18] The SpO_2 should be stable for 5 min before arterial blood sampling, otherwise the test was prolonged to 20 min. Electrocardiogram, SpO_2 and dyspnoea were continuously monitored. The patients were recommended in-flight supplemental oxygen if $PaO_{2\ HAST}$ was <6.6 kPa.[1]

Statistics

To calculate sample size, we assumed that sensitivity and specificity would be approximately 80% in the planned study. It was then shown that 100 patients were needed to construct a new algorithm in which sensitivity and specificity should have CI length <16%. Patient characteristics are presented as mean and SD, unless otherwise specified. Relations between $PaO_{2\ HAST}$ and patient characteristics were assessed from Pearson's correlation coefficient and one-way repeated measures analysis of variance. ROC analyses were performed with sea-level SpO_2, SpO_2 during 6MWT ($SpO_{2\ 6MWT}$) and walking distance against $PaO_{2\ HAST}$ <6.6 kPa as the discriminating variables. Statistical analyses were performed with PASW software (V.18.0; Chicago, Illinois, USA). Differences were considered significant if $p<0.05$.

RESULTS

Patient characteristics

The study comprised patients with COPD (n=100), with demographic characteristics as presented in table 1. According to the GOLD classification,[27] 22%, 46% and 32% were in the GOLD categories II, III and IV, respectively.

Sea-level SpO_2 was used as a grouping variable as follows: $SpO_{2\ SL}$ >95% (12% of patients), $SpO_{2\ SL}$ 92–95% (55% of patients) and $SpO_{2\ SL}$ <92% (33% of patients).

HAST

All patients were tested with HAST. Mean HAST values for PaO_2 and SpO_2 were 6.3 kPa (SD 0.6 kPa) and 83% (SD 4%), respectively. Seventy-three per cent of patients had a $PaO_{2\ HAST}$ <6.6 kPa, indicating that they, in accordance with current

Table 1 Baseline patient characteristics, n=100

		% Predicted
Sex, M/F	42/58	
Age, years	65 (8)	
BMI, kg/m^2	25 (5)	
Dyspnea, mMRC*		
Grade 0–1	16 (16%)	
Grade 2	49 (50%)	
Grade 3	17 (17%)	
Grade 4	16 (16%)	
Lung function		
FEV_1, litres	1.0 (0.4)	41.2 (13.1)
FEV_1/FVC	0.44 (0.10)	
*D*L,CO, mmol/min/kPa	3.2 (1.3)	40 (16)
*D*L,CO/VA, mmol/min/kPa/litre	0.7 (0.3)	49 (20)
TLC, litre	7.2 (1.7)	124 (24)
RV, litre	4.4 (1.4)	201 (61)
Blood gases and pulse oximetry at sea level		
PaO_2, kPa	9.0 (1.1)	
$PaCO_2$, kPa	5.0 (0.6)	
SpO_2, %	93 (3)	
Six min walk test		
Distance, m	405 (101)	
Exercise SpO_2, %	83 (6)	
Dyspnoea, Borg CR10	6.6 (2.0)	
HAST blood gases and pulse oximetry		
PaO_2, kPa	6.3 (0.7)	
$PaCO_2$, kPa	4.9 (0.6)	
SaO_2, %	83 (5)	
SpO_2, %	83 (4)	

Data are presented as n (%) and mean (SD).
*n=98.
BMI, body mass index; *D*L,CO, diffusing capacity of the lung for carbon monoxide; FEV_1% predicted, forced expiratory volume in 1 s in per cent of predicted; FVC, forced vital capacity; HAST, hypoxia-altitude simulation test; mMRC, modified Medical Research Council Dyspnea Scale; $PaCO_2$, arterial carbon dioxide pressure; PaO_2, arterial oxygen pressure; RV, residual volume; SaO_2, arterial oxygen saturation; SpO_2, arterial oxygen saturation by pulse oximetry; TLC, total lung capacity; VA, alveolar volume.

guidelines, should use in-flight supplemental oxygen. There was an increase of 0.8 (SD 1.0) in dyspnoea score (Borg CR10) ($p<0.001$). Eighteen per cent of patients reported moderate to strong dyspnoea (Borg score 3–6), but there was no significant correlation between dyspnoea score and PaO_2 $_{HAST}$ ($r=0.16$, $p=0.115$). None of the patients experienced hypoxia-induced myocardial ischaemia or arrhythmias.

Walking test

The patients covered a distance varying from 150 to 604 m during the 6MWT (table 1). The mean decrease in SpO_2 during the 6MWT was 10% (SD 5%) ($p<0.001$), and the mean SpO_2 $_{6MWT}$ was 83% (SD 6%) (table 1).

Associations between in-flight PaO_2 and sea-level characteristics

Significant correlations between sea=level characteristics and in-flight PaO_2 are presented in table 2. PaO_2 $_{SL}$, SpO_2 $_{6MWT}$ and SpO_2 $_{SL}$ showed the strongest correlation with PaO_2 $_{HAST}$ PaO_2 $_{SL}$ was not included in the further analyses since one aim of the study was to develop a non-invasive evaluation method. Diffusing capacity of the lung for carbon monoxide (*D*L,CO), *D*L,CO/alveolar volume, total lung capacity (TLC), residual volume (RV), RV/TLC and dyspnoea measured with mMRC showed no significant relationship with in-flight PaO_2.

ROC analyses were used as the basis for developing the pre-flight evaluation algorithm. SpO_2 $_{SL}$ and SpO_2 $_{6MWT}$ showed

Table 2 Variables with significant correlation to PaO_2 during HAST, n=100

Variable	r	p Value
Baseline PaO_2, kPa	0.60	<0.001
Exercise SpO_2, %	0.49	<0.001
Baseline SpO_2, %	0.47	<0.001
6MWT, distance, m	0.27	0.007
Age, years	−0.27	0.006
FEV_1, litres	0.22	0.027

6MWT, 6 min walk test; FEV_1, forced expiratory volume in 1 s; HAST, hypoxia-altitude simulation test; PaO_2, arterial oxygen pressure; SpO_2, arterial oxygen saturation by pulse oximetry.

good diagnostic properties (area under curve 0.78 and 0.79, respectively) for detection of in-flight PaO_2 <6.6 kPa (figure 2). The patients were grouped and data analysed according to the BTS pulse oximetry categories, SpO_2 $_{SL}$ >95%, 92–95% and <92% (figure 3). In the group with sea-level SpO_2 $_{SL}$ <92%, 30 of 33 (91%) patients dropped below the recommended level for minimum in-flight PaO_2 (6.6 kPa), and were thereby in need of supplemental oxygen during air travel. Regarding the 55 patients in the group with SpO_2 $_{SL}$ from 92% to 95%, a ROC analysis with SpO_2 $_{6MWT}$ showed good prognostic properties (area under curve 0.80) for detection of in-flight PaO_2 <6.6 kPa. The suggested cut-off value was SpO_2 $_{6MWT}$ <84% (sensitivity 88%, 95% CI 80% to 96%; specificity 69%, 95% CI 52% to 85%). With regard to patients with SpO_2 $_{SL}$ >95%, 5 of 12 (42%) had an in-flight PaO_2 <6.6 kPa. In this group, ROC analysis showed exercise desaturation as a good prognostic variable, with an optimal cut-off value for SpO_2 $_{6MWT}$ <84% (area under curve 0.71; sensitivity 80%, 95% CI 40% to 100%; specificity 71%, 95% CI 29% to 100%).

Algorithm

Based on the above analyses a pre-flight evaluation algorithm was constructed (figure 4). The algorithm was based on sea-level resting pulse oximetry (SpO_2 $_{SL}$) and exercise desaturation during the 6MWT (SpO_2 $_{6MWT}$) as the primary and secondary discriminator for evaluating whether the patient was fit to fly without further assessment, in need of further evaluation with HAST or should receive in-flight supplemental oxygen without further evaluation.

The pre-flight evaluation algorithm had a sensitivity of 99% (95% CI 96% to 100%) and a specificity of 82% (95% CI 67% to 96%) when all 100 subjects were individually tested. According to the algorithm, one-third (33%) of the patients would be advised to perform extended pre-flight testing with HAST. Six per cent of the patients were not correctly classified by the algorithm; of these, one patient was misclassified as fit to fly despite a PaO_2 $_{HAST}$ <6.6 kPa (SpO_2 $_{SL}$ 97% and SpO_2 $_{6MWT}$ 87%, measured PaO_2 $_{HAST}$ 6.3 kPa), and five patients would have been recommended to use in-flight oxygen without, in fact, having a PaO_2 $_{HAST}$ <6.6 kPa (mean PaO_2 $_{HAST}$ 7.2 kPa (SD 0.3 kPa)). The patients selected by the algorithm for further pre-flight evaluation with HAST had a mean PaO_2 $_{HAST}$ of 6.6 kPa (SD 0.6 kPa).

After the algorithm was established, it was prospectively validated on an independent sample of 50 patients with COPD who were referred to HAST (table 3). Eight patients had SpO_2 $_{SL}$ >95% (16%), 27 patients had SpO_2 $_{SL}$ 92–95% (54%) and 15 patients had SpO_2 $_{SL}$ <92% (30%). For all but four patients a correct choice was obtained with regard to use of in-flight supplemental oxygen. These four patients were recommended

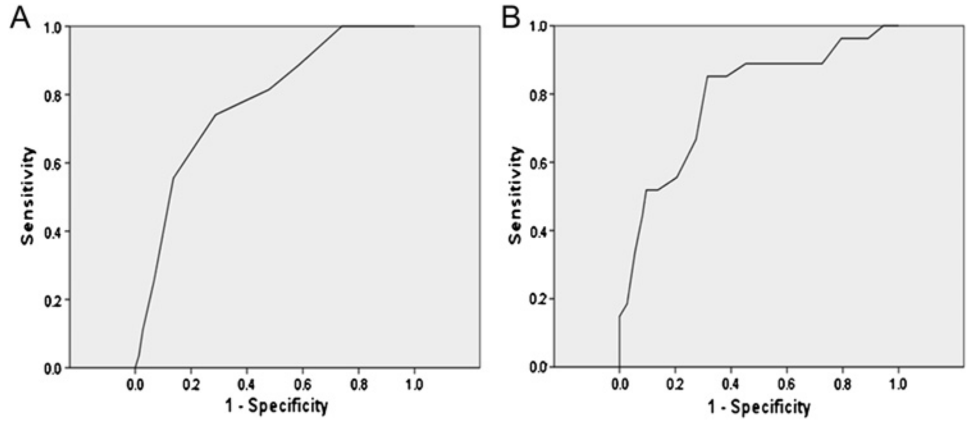

Figure 2 Receiver operating characteristics curves: (A) sea-level SpO_2, with $PaO_{2\ HAST}$ <6.6 kPa or ≥6.6 kPa as the discriminating variable, area under curve 0.78; and (B) SpO_2 during the 6MWT, with $PaO_{2\ HAST}$ <6.6 kPa or ≥6.6 kPa as the discriminating variable, area under curve 0.79. 6MWT, 6 min walk test; HAST: hypoxia-altitude simulation test; PaO_2, arterial oxygen pressure; SpO_2, arterial oxygen saturation measured with pulse oximetry.

supplemental oxygen without having a $PaO_{2\ HAST}$ <6.6 kPa. However, it should be noted that they all had $PaO_{2\ HAST}$ values close to the recommended limit (mean $PaO_{2\ HAST}$ 6.6 kPa (SD 0.1 kPa)). The sensitivity and specificity for the algorithm in this independent sample of patients were 100% (95% CI 90% to 100%) and 80% (95% CI 60% to 95%), respectively. The 20 patients which the algorithm selected for further pre-flight evaluation with HAST had a mean $PaO_{2\ HAST}$ of 6.9 kPa (SD 0.5 kPa).

HAST: PaO_2 versus SpO_2

The secondary aim was to evaluate if HAST can be performed with SpO_2 as a substitute for PaO_2. There was a strong correlation between $PaO_{2\ HAST}$ and $SpO_{2\ HAST}$ (r=0.81, p<0.001) during HAST. The area under the ROC curve when using pulse oximetry to detect in-flight PaO_2 <6.6 kPa was 0.93, indicating strong prognostic properties for the method (figure 5). The analysis suggested a cut-off value for $SpO_{2\ HAST}$ ≤85% with a sensitivity of 89% (95% CI 81% to 96%) and a specificity of 81% (95% CI 67% to 96%) when $SpO_{2\ HAST}$ was used as a substitute for $PaO_{2\ HAST}$ <6.6 kPa (figure 5). When using $SpO_{2\ HAST}$, instead of $PaO_{2\ HAST}$ an independent sample of 50 patients with COPD, we obtained a sensitivity of 90% (95% CI 77% to 100%) and a specificity of 85% (95% CI 70% to 100%). Three patients were misclassified as fit to fly despite having $PaO_{2\ HAST}$ <6.6 kPa (mean $PaO_{2\ HAST}$ 6.3 kPa), and three patients would have been recommended to use in-flight oxygen without, in fact, having a $PaO_{2\ HAST}$ <6.6 kPa (mean $PaO_{2\ HAST}$ 6.7 kPa).

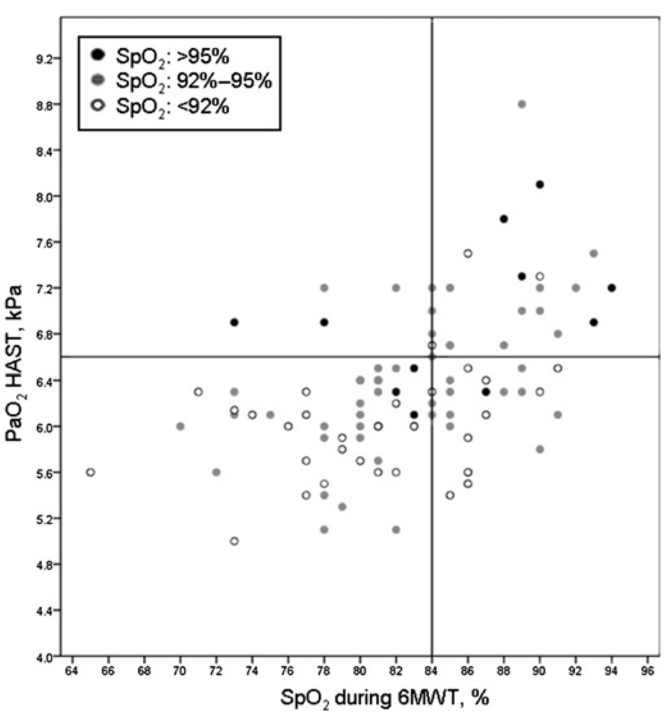

Figure 3 SpO_2 during 6MWT versus $PaO_{2\ HAST}$. Patients are grouped after sea-level SpO_2 >95%, 92–95% and <92%. Recommended level for minimum in-flight PaO_2 (6.6 kPa) and cut-off for exercise desaturation (84%) is marked. 6MWT, 6 min walk test; HAST, hypoxia-altitude simulation test; PaO_2, arterial oxygen pressure; SpO_2, arterial oxygen saturation measured with pulse oximetry; ●, SpO_2 >95%; ●, SpO_2 92–95%; ○, SpO_2 <92%.

DISCUSSION

A large number of patients with COPD travel by air, most of them without severe in-flight medical problems.[9 13] However, some patients develop severe hypoxaemia.[1 2 4–7] Thus, simple and consistent pre-flight assessment guidance regarding the need for in-flight supplemental oxygen has been requested.[1 3 11] In the present study we have constructed and validated a simple and clinically feasible algorithm for pre-flight assessment of patients with COPD based on sea-level resting SpO_2 and SpO_2 values during a 6MWT.

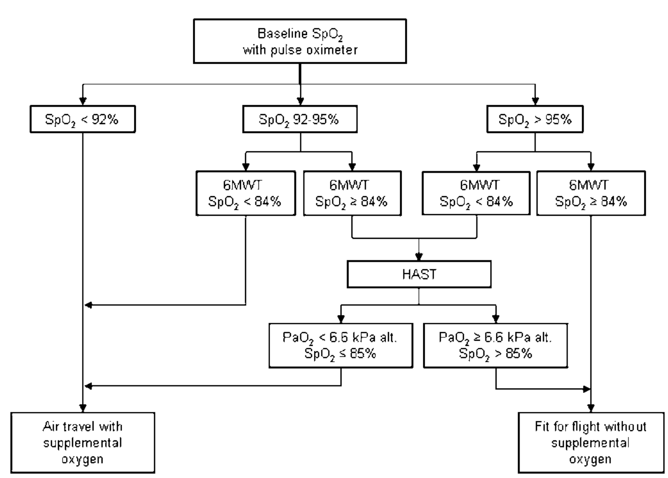

Figure 4 Pre-flight evaluation algorithm. 6MWT, 6 min walk test; alt, alternatively; HAST, hypoxia-altitude simulation test; PaO_2, arterial oxygen pressure; SpO_2, arterial oxygen saturation measured with pulse oximetry.

Table 3 Baseline characteristics for patients used in the separate validation of the algorithm, n=50

		% Predicted
Sex, M/F	25/25	
Age, years	64 (8)	
Lung function		
FEV_1, litres	1.1 (0.4)	40.2 (15.1)
FEV_1/FVC	0.41 (0.09)	
*D*L,CO, mmol/min/kPa	3.0 (1.5)	36 (17)
*D*L,CO/VA, mmol/min/kPa/litre	0.6 (0.3)	44 (21)
TLC, litres	7.6 (1.6)	127 (21)
RV, litres	4.4 (1.3)	198 (50)
Blood gases and pulse oximetry at sea level		
PaO_2, kPa	9.0 (1.1)	
$PaCO_2$, kPa	5.1 (0.6)	
SpO_2, %	93 (3)	
Six min walk test		
Distance, m	425 (109)	
Exercise SpO_2, %	82 (4)	
Dyspnoea, Borg CR10	6.4 (2.2)	
HAST blood gases and pulse oximetry		
PaO_2, kPa	6.5 (0.5)	
$PaCO_2$, kPa	4.9 (0.6)	
SaO_2, %	85 (4)	
SpO_2, %	85 (4)	

Data are presented as n (%) and mean (SD).
*D*L,CO, diffusing capacity of the lung for carbon monoxide; FEV_1%predicted, forced expiratory volume in 1 s in per cent of predicted; FVC, forced vital capacity; HAST, hypoxia-altitude simulation test; $PaCO_2$, arterial carbon dioxide pressure; PaO_2, arterial oxygen pressure; RV, residual volume; SaO_2, arterial oxygen saturation; SpO_2, arterial oxygen saturation by pulse oximetry; TLC, total lung capacity; VA, alveolar volume.

Various proposed equations and single sea-level variables have proven not to predict in-flight hypoxaemia with a satisfactory precision.[1 3–5 16 22] Several authors have suggested that exercise-related outcomes may be useful discriminators.[4 5 14 24 25] Previous studies from our group show that aerobic capacity correlates with in-flight hypoxaemia.[4 5] Chetta *et al* showed that desaturation during the 6MWT provides useful information in the pre-flight assessment.[24] Since oxygen saturation measured with pulse oximetry, at rest and during a 6MWT, is frequently used in the medical care of patients with COPD,[31] an algorithm employing a combination of these variables would be simple to implement in a busy clinical practice. An assessment algorithm that can discriminate between patients who will need supplemental oxygen during air travel and those who can travel without such equipment would be of considerable value in the evaluation of patients with COPD intending to travel by air, especially if the number of unequivocal findings needing more extensive pre-flight evaluation is reduced.

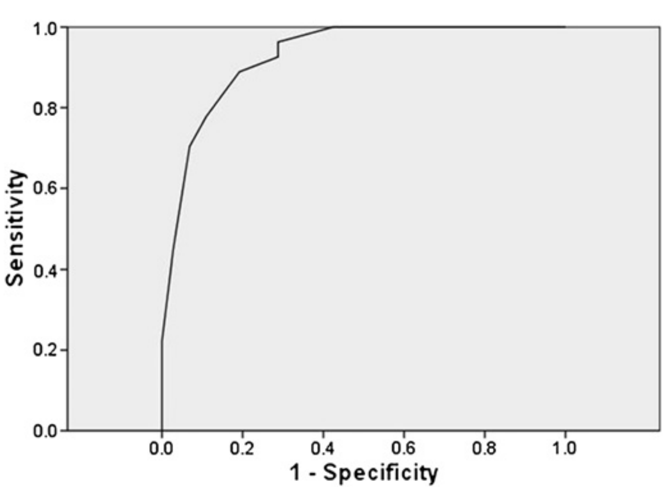

Figure 5 Receiver operating characteristics curve of $SpO_{2\ HAST}$ as a substitute for $PaO_{2\ HAST}$ < or ≥6.6 kPa, area under curve 0.93. HAST, hypoxia-altitude simulation test; PaO_2, arterial oxygen pressure; SpO_2, arterial oxygen saturation measured with pulse oximetry.

The results from our group have previously indicated that the BTS algorithm with only sea-level SpO_2 cannot be used with confidence to predict in-flight hypoxaemia.[23] A large number of patients at risk of developing severe hypoxaemia was not detected, and a considerable number of patients needed more advanced pre-flight evaluation.[23] By adding a 6MWT, including measurement of SpO_2, the current study shows that the number of patients needing referral to HAST was markedly reduced. The 6MWT is a widely used test to assess exercise performance in patients with COPD, and is much more available than HAST. However, it is important that the 6MWT is performed according to guidelines, and it must be stressed that shortcuts must be avoided.[29] The suggested algorithm has a high sensitivity, which was reproduced when applying it prospectively on a separate group of patients with COPD. None of these study subjects were misclassified as fit to fly without supplemental oxygen. Due to somewhat lower specificity, the algorithm overestimated the risk of in-flight hypoxaemia, resulting in unnecessary use of supplemental oxygen in 8% of the patients.

According to our results, patients with COPD who have $SpO_{2\ SL}$ >95% and without severe exertional desaturation (SpO_2 ≥84%) can travel safely by air without further pre-flight assessment. In addition, further pre-flight assessment is not necessary in patients with $SpO_{2\ SL}$ <92%[13 23] or in patients with $SpO_{2\ SL}$ 92–95% and $SpO_{2\ 6MWT}$ <84%. These patients should, according to our results, be equipped with supplemental oxygen during the flight. Thus, extended pre-flight assessment with HAST might be limited to patients with either the combination of resting $SpO_{2\ SL}$ >95% and severe exercise desaturation (SpO_2 <84%) and to patients with $SpO_{2\ SL}$ between 92% and 95% without severe exercise desaturation (≥84%). In these two groups of patients, the level of in-flight hypoxaemia was difficult to predict, underlining the need for pre-flight testing with HAST.

Even though HAST is increasingly used in pre-flight assessment,[32 33] it is not widely available.[11 21] HAST has been shown to be a good predictor of in-flight PaO_2[18 32 34 35] and the results obtained are reproducible.[32] However, one might find it cumbersome to take repeated arterial blood samples or insert a radial artery catheter, and substitution of arterial blood gas measurement with pulse oximetry would simplify the HAST procedure considerably. To our knowledge, comparison of arterial blood gases and pulse oximetry during HAST has not previously been published. As expected, a strong correlation between $PaO_{2\ HAST}$ and $SpO_{2\ HAST}$ was observed, and when using a cut-off value for $SpO_{2\ HAST}$ ≤85% as a substitute for a $PaO_{2\ HAST}$ <6.6 kPa, acceptable values for sensitivity and specificity of the test were obtained. Our results show that use of pulse oximetry during HAST may underestimate the need for in-flight oxygen. Thus, the authors would recommend arterial blood gas measurement during HAST as the method of choice.

To our knowledge, this is the first prospective study to use a set of common baseline characteristics for the construction of a pre-flight evaluation algorithm. The good prognostic properties of the algorithm were confirmed by a prospective validation on a separate group of subjects with COPD. However, it should be noted that a selected group of patients was studied; they were all referred for pre-flight evaluation. These are the patients for whom the algorithm is intended. One must also keep in mind that the present study only comprised patients with moderate to very severe COPD[27] and that the algorithm may not be applicable to patients with other lung diseases.

In conclusion, an algorithm for pre-flight evaluation of patients with COPD is presented, employing simple non-invasive oximetry at rest and during walking. By using the algorithm, the majority of a population consisting of patients with moderate to very severe COPD could be classified as fit to fly or in need of supplemental oxygen without more advanced pre-flight assessment.

Acknowledgements Leiv Sandvik, Professor in Biostatistics, Oslo University Hospital, is gratefully acknowledged.

Contributors AE and MR: conception and design of the study, collecting, analysing and interpreting the data, drafting and revising the manuscript. AA: conception and design of the study, interpreting the data, drafting and revising the manuscript. CCC: conception and design of the study, collecting and interpreting the data, drafting and revising the manuscript. OHS: conception and design of the study, analysing and interpreting the data, drafting and revising the manuscript.

Funding The study was funded by grants from The Norwegian Heart and Lung Patient Organisation and The Norwegian Foundation for Health and Rehabilitation.

Competing interests None.

Ethics approval Ethics approval was provided by The Regional Norwegian Committee for Medical Research Ethics.

Provenance and peer review Not commissioned; externally peer reviewed.

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