Assessment of oxygen supplementation during air travel

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Abstract

Background **– The aim of this study was to simulate an in flight environment at sea level with a fractional inspired concentration of oxygen (Fio$_2$) of 0·15 to determine how much supplemental oxygen was needed to restore a subject's oxygen saturation (Sao$_2$) to 90% or to the level previously attained when breathing room air (Fio$_2$ of 0·21).**

Methods **– Three groups were selected with normal, obstructive, and restrictive lung function. Using a sealed body plethysmograph an environment with an Fio$_2$ of 0·15 was created and mass spectrometry was used to monitor the Fio$_2$. Supplemental oxygen was administered to the patient by nasal cannulae. Sao$_2$ was continuously monitored and recorded at an Fio$_2$ of 0·21, 0·15, and 0·15 + supplemental oxygen.**

Results **– When given 2 l/m of supplemental oxygen all patients in the 15% environment returned to a similar Sao$_2$ value as that obtained using the 21% oxygen environment. One patient with airways obstruction needed 3 l/m of supplemental oxygen to raise his Sao$_2$ above 90%.**

Conclusions **– This technique, which simulates an aircraft environment, enables an accurate assessment to be made of supplemental oxygen requirements.**

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Keywords: fractional concentration of inspired oxygen (Fio$_2$), supplemental oxygen, oxygen saturation (Sao$_2$).

During commercial flights most cabins are pressurised to an equivalent altitude of 5000–8000 feet.[1] This equates to an inspired oxygen fraction (Fio$_2$) of 0·17–0·15 at sea level.[2]

Fitness to fly tests are currently performed by giving a hypoxic mixture in a Douglas bag.[3] This test procedure has limitations with patients who are hypoxaemic and may require supplemental oxygen during the flight. This new technique enables the required oxygen flow rate to be titrated to the patients' requirements.

Mean (SD) characteristics of subjects in study

	Normal subjects (n = 10)	Obstructive subjects (n = 10)	Restrictive subjects (n = 10)
M:F	4:6	6:4	6:4
Age (years)	32 (7·0)	49 (21·5)	55 (10·1)
FEV$_1$ (% pred)	103 (10·4)	31 (17·4)	56 (17·5)
FVC (% pred)	114 (10·5)	64 (21·7)	58 (18·7)
FEV$_1$/FVC %	77 (7·8)	40 (12·7)	81 (9·9)
Tlco (% pred)	97 (14·2)	48 (22·7)	38 (18·3)
Kco (% pred)	105 (16·0)	76 (24·1)	88 (19·3)

FEV$_1$ = forced expiratory volume in one second; FVC = forced vital capacity; Tlco = transfer factor for carbon monoxide; Kco = transfer coefficient.

Methods

SUBJECTS

Sixteen men and 14 women underwent routine lung function testing (table). Normal ranges were obtained using the European Community for Steel and Coal (ECSC) prediction equations.[4] All subjects were assessed by the fitness to fly protocol. All participants gave written informed consent to the experimental procedures which were approved by the ethics committee of the Royal Brompton Hospital.

MEASUREMENTS

Tests were performed using a body plethysmograph (Fenyves & Gut, Switzerland), transfer factor tests (P K Morgan Ltd, UK), flow-volume loops (P K Morgan Ltd; Brompton Software), pulse oximetry (Ohmeda Ltd, UK), and Fio$_2$ using a mass spectrometer (Airspec Ltd, UK).

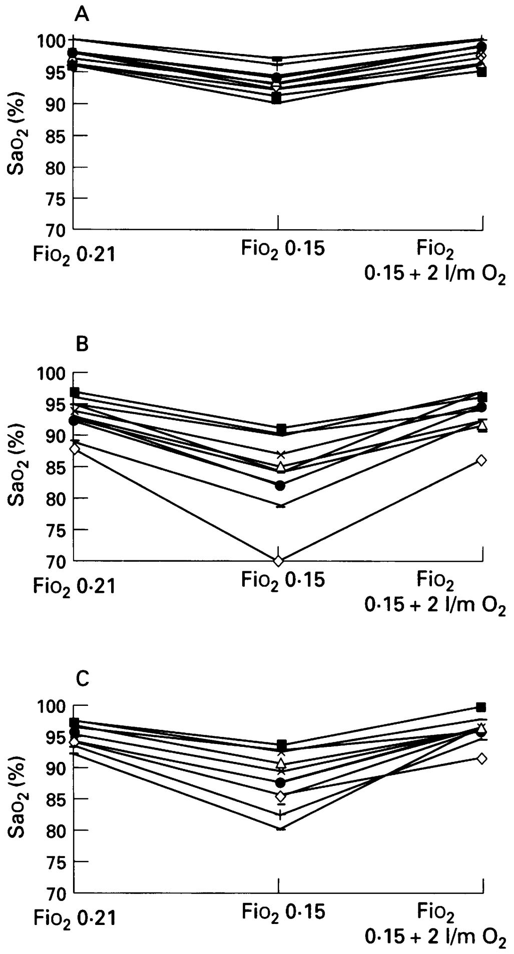
PROTOCOL

The plethysmograph was modified, allowing it to be used as a sealed chamber in which the Fio$_2$ could be varied by adding oxygen or nitrogen through a communicating port. Two other communicating ports were utilised, one for additional oxygen administration to the patient via nasal cannulae and the other to enable a mass spectrometer to monitor Fio$_2$ continuously. The mass spectrometer was calibrated before each study.

Due to the physical constraints of the plethysmograph it was inappropriate to take blood gas samples from the patient. Continuous monitoring of arterial oxygen saturation (Sao$_2$) was performed using a finger probe attached to a pulse oximeter (response time three seconds).

Each subject sat in the plethysmograph which was then closed and the Fio$_2$ was continuously monitored. By the addition of nitrogen through the communicating port the Fio$_2$ was reduced from 0·21 to 0·15 and Sao$_2$ values were recorded at each Fio$_2$. Supplemental oxygen was given via nasal cannulae at an initial flow of 2 l/m with the subject breathing an Fio$_2$ of 0·15. A further measurement of Sao$_2$ was performed.

In any subject whose Sao$_2$ was less than 90% breathing 2 l/m oxygen, additional measurements were performed using higher oxygen



Sao$_2$ (%) measured in different environments with and without supplemental oxygen in (A) normal subjects, (B) subjects with obstructive lung function, and (C) subjects with restrictive lung function.

flows (3 or 4 l/m) until an Sao$_2$ of >90% was obtained.

Patients were in the plethysmograph approximately 10 minutes with no rise in ambient oxygen concentration as nitrogen was continually added to maintain an Fio$_2$ of 0·15. Measurements of Sao$_2$ were recorded once equilibration was obtained as demonstrated by a stable Sao$_2$ reading.

DATA ANALYSIS

Data were analysed using a statistics package (SPSS for Windows, Version 6·0). Comparisons of oxygen saturation within groups at different inspired oxygen concentrations were made by the Wilcoxon signed rank test. Comparisons between groups were made by the Kruskal-Wallis analysis of variance (three groups).

Results

For subjects studied in the plethysmograph with an Fio$_2$ of 0·21 the median Sao$_2$ was 96% (range 88–100%). When the Fio$_2$ was reduced to 0·15 a significant drop in Sao$_2$ occurred ($p = 0·02$), the median value being 90% (range 70–97%); however, the absolute fall in Sao$_2$ in normal subjects was minimal due to the shape of the dissociation curve. With the Fio$_2$ at 0·15 and the addition of supplemental oxygen at 2 l/m the median value was 95·5% (range 86–100%).

No significant difference was found in oxygen saturation values when breathing an Fio$_2$ of 0·21 or an Fio$_2$ of 0·15 with oxygen delivered at 2 l/m, in all 30 subjects ($p = 0·46$) or within the three groups ($p = 0·91$). However, one subject with a forced expiratory volume in one second (FEV$_1$): forced vital capacity (FVC) ratio of 36% and a transfer factor for carbon monoxide (Tlco) of 26% predicted had an Sao$_2$ result of 88% when breathing an Fio$_2$ of 0·21. In the simulated aircraft environment breathing 2 l/m oxygen the Sao$_2$ was 86%. When oxygen was given at 3 l/m the Sao$_2$ increased to 94%.

Discussion

Although respiratory crises on aircraft are very rare, the cabin provides a potentially hazardous environment.[5] Utilising existing lung function equipment has enabled us to assess the effect of supplemental oxygen during simulated air travel. Although a mass spectrometer was used, oxygen analysers with a response time of less than six seconds could also be utilised. The potential risks of giving patients with severe hypoxaemia a gas mixture with an Fio$_2$ of 0·15 have been overcome by administering supplemental oxygen whilst gradually reducing the Fio$_2$ in the plethysmograph, suggesting that when subjects are given oxygen at a flow rate of 2 l/m, breathing an Fio$_2$ of 0·15, their oxygen saturation nearly always reverts to the value obtained when breathing an Fio$_2$ of 0·21 (figure).

Knowing the required oxygen flow rate and the flight duration, an accurate assessment of oxygen requirements can be calculated and the size and number of cylinders prescribed accordingly. For instance, a size F oxygen cylinder (1360 litres) is sufficient when administered at 2 l/m for an 11 hour flight. The charge levied for cylinders varies according to the airline company.

Arterial carbon dioxide (Paco$_2$) measurements were not performed. Provided supplemental oxygen does not raise Sao$_2$ above the patients' usual level, no significant change in Paco$_2$ will occur. However, one patient required 3 l/m of supplemental oxygen to achieve an Sao$_2$ of >90%. If this is considered desirable during flight, further testing with measurement of Paco$_2$ would be required.

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