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Nocturnal saturation and respiratory muscle function in patients with chronic obstructive pulmonary disease

Y F Heijdra, P N R Dekhuijzen, C L A van Herwaarden, H Th M Folgering

Abstract

***Background* – Nocturnal desaturations, mainly caused by hypoventilation, occur frequently in patients with chronic obstructive pulmonary disease (COPD). Daytime arterial oxygen and carbon dioxide tensions (Pa_{O_2} and Pa_{CO_2}) appear to predict which patients will desaturate at night. It is unknown if respiratory muscle strength, which may be decreased in these patients, plays an additional part.**

***Methods* – Polysomnography, maximal respiratory pressures, lung function, and arterial blood gas tensions were measured in 34 patients with COPD (mean (SD) forced expiratory volume in one second (FEV_1) 41·7 (19·9)% pred).**

***Results* – Significant correlations were found between the mean nocturnal arterial oxygen saturation and maximal inspiratory mouth pressure ($r = 0{\cdot}65$), maximal inspiratory transdiaphragmatic pressure ($r = 0{\cdot}53$), FEV_1 ($r = 0{\cdot}61$), transfer coefficient (KCO) ($r = 0{\cdot}38$), arterial oxygen saturation (Sa_{O_2}) ($r = 0{\cdot}75$), and Pa_{CO_2} ($r = -0{\cdot}44$). Multiple regression analysis showed that 75% of the variance in nocturnal Sa_{O_2} was explained by a combination of Sa_{O_2} (70%) and FEV_1 (5%).**

***Conclusion* – Inspiratory muscle strength and nocturnal saturation data are correlated, but daytime Sa_{O_2} and FEV_1 remain the most important predictors of nocturnal saturation.**

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Keywords: nocturnal saturation, respiratory muscle strength, chronic obstructive pulmonary disease.

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The main cause of arterial oxygen desaturations associated with rapid eye movement (REM) sleep is hypoventilation.[1] This, in turn, is partly determined by decreased intercostal and accessory muscle activity due to a lowered motor command.[2] The diaphragm has to compensate for the diminished activity of these muscles during REM sleep. In patients with chronic obstructive pulmonary disease (COPD), however, strength and endurance of the diaphragm may be affected by their unfavourable position on the length-tension curve due to hyperinflation.[3]

Daytime arterial oxygen and carbon dioxide tensions (Pa_{O_2} and Pa_{CO_2}) predict 65–75% of the variance in nocturnal saturation.[4,5] It is unknown if respiratory muscle strength has an additional role. The purpose of the present study was therefore to evaluate the relation between inspiratory muscle strength and nocturnal saturation in 34 stable patients with COPD. In addition, the contribution of inspiratory muscle strength to the prediction of nocturnal saturation was investigated.

Methods

Thirty four patients with stable COPD[6] (30 men, mean (SD) forced expiratory volume in one second (FEV_1) 41·7 (19·9)% pred) were included in the study which was approved by the hospital medical ethics committee. Patients with an obstructive sleep apnoea syndrome or an overlap syndrome were excluded.

Polysomnography was performed including arterial oxygen saturation, heart rate, end tidal P_{CO_2} (P_{ETCO_2}), thoracic movements, and electro-oculography (EOG). Oxygen saturation (Sa_{O_2}) and heart rate were measured in a real time format by a pulse oximeter. A desaturation was defined by a combination of the definition of Block *et al*[7] and Fletcher *et al*[8] as a decrease by more than 4% in oxygenation from the baseline saturation when awake for a period of five minutes or more. P_{ETCO_2} was measured with a sampling capnograph by introducing a catheter into the nasopharyngeal cavity. The baseline awake and asleep Sa_{O_2} and P_{ETCO_2} were defined as the mean Sa_{O_2} and P_{ETCO_2} during the first 15 minutes of the record and while asleep, respectively. Since P_{ETCO_2} is not representative of arterial P_{CO_2}, increases in P_{ETCO_2} signals were only used qualitatively as indicators of hypoventilation[9] in combination with saturation and thoracic movement signals. Thoracic movements were analysed by respiratory inductive plethysmography. An EOG was measured with surface electrodes and used for visual scoring of wakefulness, non-REM and REM sleep, in combination with the other signals.[10] When rapid eye movements were present and desaturations occurred in the absence of gross body movements, it was even more likely that REM sleep was present.[11]

Static maximal inspiratory and expiratory mouth pressures (P_{Imax}, P_{Emax}), as well as static maximal inspiratory transdiaphragmatic pressure (P_{DI}), were measured as described previously.[12] The inspiratory manoeuvre at residual volume (RV) and the expiratory manoeuvre at total lung capacity (TLC) were repeated until three reproducible measurements had been made with a maximal variability of 10%. The highest values were used for analysis. The inspiratory pressures were

Table 1 Mean (SD) nocturnal measurements

Baseline Sao_2 awake (%)	93·5 (2·5)
Mean nocturnal Sao_2 (%)	90·6 (4·5)
% time desaturated (%)	19·1 (27·8)
Lowest nocturnal Sao_2 (%)	83·3 (12·2)
Baseline $PETCO_2$ awake (kPa)	5·0 (0·7)
$PETCO_2$ asleep (kPa)	5·5 (0·9)
Time in bed (min)	454 (48)
Time in non-REM (min)	249 (69)
Time in REM (min)	49 (21)

Sao_2 = arterial oxygen saturation; $PETCO_2$ = end tidal carbon dioxide tension; REM = rapid eye movement sleep.

expressed as absolute values. Predicted values for respiratory muscle strength were derived from Wilson *et al.*[13]

DATA ANALYSIS

Data are presented as means (SD). Spearman correlation tests were performed, p values of <0·05 being considered significant. Stepwise multiple regression analysis was used to assess which parameters were independent predictors of the nocturnal and daytime saturation. The significance level for retention in the model was 0·05.

Results

The mean age of the patients was 61·4 (6·4) years. They had a wide variation of airways obstruction (FEV_1 0·6–3·2 l, mean 41·7 (19·9)% pred). They were hyperinflated (functional residual capacity (FRC) (127·8 (31·2)% pred)) and had a low gas transfer coefficient capacity (Kco) of 57·5 (28·5)% pred. Four patients were hypoxaemic (Pao_2 <8·0 kPa) and two patients were hypoxaemic and hypercapnic ($Paco_2$ >6·5 kPa). The mean Pao_2 and $Paco_2$ were 9·3 (1·3) kPa and 5·7 (0·7) kPa, respectively.

All patients had at least one period of REM sleep and, in the whole group, 10·8 (4·6)% of the recording time was spent in REM sleep. Of the 34 patients 16 developed episodes with desaturations during the night. In these 16 patients the mean desaturation time and the mean REM sleep time were 40·6 (27·7)% and 11·6 (4·0)% of the total recording time, respectively. In these patients 64·0 (35·2)% of the total REM sleep time was spent desaturated, which represents 18·2% of the total desaturation time. The polysomnographic data are shown in table 1.

Pimax, Pdi, and Pemax were 6·9 (2·3) kPa (87·5 (27)% pred), 9·7 (3·6) kPa, and 8·9 (3·0) kPa (73·1 (22·2)% pred), respectively. In four patients Pdi was not measured because of inability to swallow the oesophageal catheter. The correlation coefficients between nocturnal saturation data and daytime characteristics are presented in table 2. The highest correlation coefficient was found between daytime and nocturnal saturation.

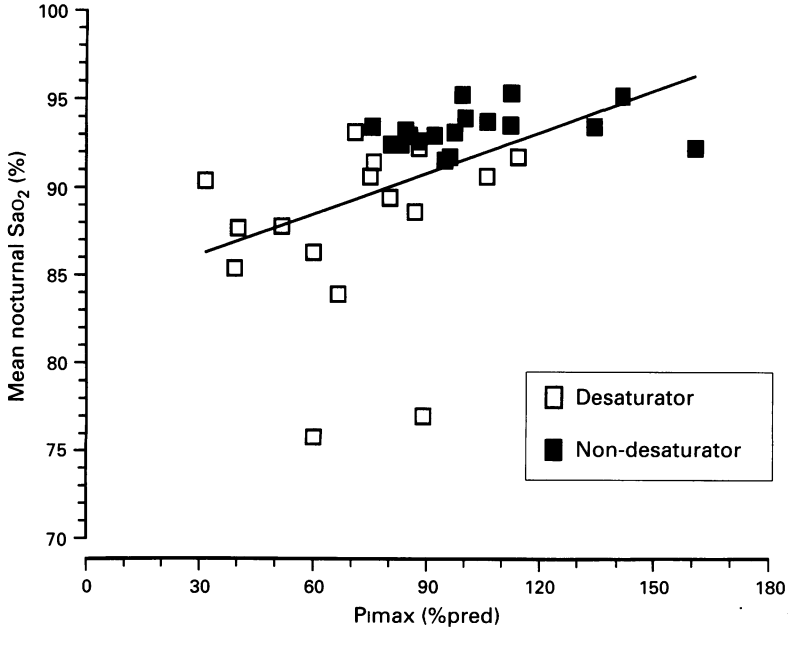
The correlation between Pimax (% pred) and mean nocturnal arterial oxygen saturation (Sao_2) (%) is shown in the figure. There was a large overlap between patients who did and did not desaturate.

Stepwise multiple regression analysis was used to evaluate the contribution of various parameters in the prediction of the mean nocturnal saturation. The input variables were the daytime parameters shown in table 2. Of the variance in mean nocturnal Sao_2, 75% was explained by a combination of daytime Sao_2 (70%) and FEV_1 (5%). A similar analysis was performed to predict daytime Sao_2 with the variables Pimax (kPa), Pdi (kPa), FEV_1 (% pred), FRC (% pred), and Kco (% pred). Pdi was the only predictive variable ($r^2 = 0·33$).

Table 2 Spearman's correlation coefficients between daytime characteristics and nocturnal saturation data

Daytime parameters	*Mean nocturnal Sao_2 (%)*	*Lowest nocturnal Sao_2 (%)*	*% time desaturated (%)*
Pimax (kPa)	0·65***	0·60***	−0·64***
Pdi (kPa)	0·53**	0·47**	−0·60***
Sao_2 (%)	0·75***	0·64***	−0·67***
$Paco_2$ (kPa)	−0·44**	−0·45**	0·47**
FEV_1 (%pred)	0·61***	0·53**	−0·58***
Kco (% pred)	0·39*	0·36	−0·34*

Pimax = static maximal inspiratory mouth pressure; Pdi = static maximal inspiratory transdiaphragmatic pressure; Sao_2 = arterial oxygen saturation; $Paco_2$ = arterial carbon dioxide tension; FEV_1 = forced expiratory volume in one second; Kco = carbon monoxide transfer coefficient. * p<0·05; ** p<0·01; *** p<0·001.



Relation between maximal inspiratory mouth pressure (Pimax) (% pred) and mean nocturnal arterial oxygen saturation (%); r = 0·63, p<0·001.

Discussion

This study shows that maximal inspiratory muscle strength and nocturnal saturation data are significantly correlated in patients with COPD. However, daytime Sao_2 and FEV_1 remain the most important predictors of nocturnal saturation.

An important case of hypoventilation during REM sleep is diminished respiratory activity of the intercostal and accessory muscles[14] which increases the workload of the diaphragm. However, strength and endurance of the diaphragm in patients with COPD may be affected by their unfavourable position on the length-tension curve due to hyperinflation.[3] It was therefore hypothesised that a relation may exist between nocturnal arterial oxygen saturation and maximal inspiratory muscle strength, and a sig-

nificant correlation was, indeed, shown between these two parameters (figure). However, if patients were divided into those who desaturated and those who did not, a considerable overlap was seen between the two groups. PImax and PDI appear to have a low predictive value and this was confirmed by multiple regression analysis. Daytime Sa_{O_2} and FEV_1 were the only independent predictors and explained 75% of the variance in the mean nocturnal saturation. However, PDI was the only predictive variable for daytime Sa_{O_2} so an indirect effect on nocturnal saturation via daytime Sa_{O_2} is also possible. The finding that FEV_1 was one of the independent predictors, in contrast to other studies,[15 16] may be explained by the wide range of FEV_1 values (0·6–3·2 l) in our patients.

The significance of daytime Sa_{O_2} in predicting the nocturnal saturation has been described previously. Bradley *et al*[4] showed that daytime Sa_{O_2} and Pa_{CO_2} accounted for 68% of the variability of the nocturnal saturation in patients with COPD. In another study a high correlation was found between daytime and nocturnal Sa_{O_2} in 97 patients with COPD.[5]

The definition of a desaturation as a decrease of more than 4% in Sa_{O_2} lasting at least five minutes was derived from the study of Block *et al*[7] combined with that of Fletcher *et al*[8] who defined a nocturnal desaturation as a fall below 90% lasting at least five minutes or more. This latter study described desaturations in patients with COPD in whom, in general, a serious desaturation lasted longer than five minutes, in contrast to patients with obstructive sleep apnoea in whom clinically important desaturations can last as little as 10 seconds. In addition, desaturations caused by movement usually last less than five minutes.

The patients in this study spent a long time awake. This is probably due to the long recording time, defined as the total time patients spent in bed attached to the polysomnographic apparatus, because the time spent in REM and non-REM sleep was comparable to other sleep studies performed in patients with COPD.[5 8 11 16 17] When the total recording time and the time patients were awake in our study were compared with the study of Gothe *et al*[17] similar results were found. The total recording time and the time spent awake were 454 (48) minutes versus 449 (80) minutes, and 156 (58) minutes versus 188 (85) minutes in our study and that of Gothe *et al*, respectively.

Little is known about the impact of an experimental situation on sleep stage variability, Sa_{O_2}, and breathing pattern in patients with COPD. Two studies have shown that mean and lowest Sa_{O_2} and breathing pattern did not differ during two nights.[17 18] Based on these data we presume that the outcome of the present study was not influenced by studying patients for only one night.

In conclusion, this study shows significant correlations between maximal inspiratory muscle strength and nocturnal saturation data in patients with COPD. However, 75% of the variability in mean nocturnal Sa_{O_2} was explained by daytime Sa_{O_2} and FEV_1.

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