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 (PaO₂ and PaCO₂) 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 (FEV₁) 41·7 (19·9)% pred). Significant correlations were found between the mean nocturnal arterial oxygen saturation and maximal inspiratory mouth pressure (r = 0·65), maximal inspiratory transdiaphragmatic pressure (r = 0·53), FEV₁ (r = 0·61), transfer coefficient (KCO) (r = 0·38), arterial oxygen saturation (SaO₂) (r = 0·75), and PaCO₂ (r = -0·44). Multiple regression analysis showed that 75% of the variance in nocturnal SaO₂ was explained by a combination of SaO₂ (70%) and FEV₁ (5%).

Results - Inspiratory muscle strength and nocturnal saturation data are correlated, but daytime SaO₂ and FEV₁ remain the most important predictors of nocturnal saturation.

Conclusion - Inspiratory muscle strength and nocturnal saturation are associated with rapid eye movement (REM) sleep hypoventilation. This, in turn, is partly determined by decreased intercostal and accessory muscle activity due to a lowered motor command. 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 hyper-inflation.

Keywords: nocturnal saturation, respiratory muscle strength, chronic obstructive pulmonary disease.
Nocturnal saturation and respiratory muscle function in COPD

Pimax (kPa)

FEV₁ = forced expiratory volume in one second; Kco = carbon monoxide transfer coefficient.

Pimax = static maximal inspiratory mouth pressure; Kco (%) = carbon monoxide transfer coefficient.

Sao₂ = arterial oxygen saturation; Paco₂ = arterial 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 (FEV₁ 0·6-3·21, 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 (Pao₂ <8·0 kPa) and two patients were hypoxaemic and hypercapnic (Paco₂ >6·5 kPa). The mean Pao₂ and Paco₂ 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 Pmax 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 Pmax (% pred) and mean nocturnal arterial oxygen saturation (Sao₂) (%) 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 Sao₂, 75% was explained by a combination of daytime Sao₂ (70%) and FEV₁ (5%). A similar analysis was performed to predict daytime Sao₂ with the variables Pimax (kPa), Pdi (kPa), FEV₁ (% pred), FRC (% pred), and Kco (% pred). Pdi was the only predictive variable (r² = 0·33).

Discussion

This study shows that maximal inspiratory muscle strength and nocturnal saturation data are significantly correlated in patients with COPD. However, daytime Sao₂ and FEV₁ 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 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. It was therefore hypothesised that a relation may exist between nocturnal arterial oxygen saturation and maximal inspiratory muscle strength, and a sig-
significant 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 Sao2 and FEV1 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 Sao2 so an indirect effect on nocturnal saturation via daytime Sao2 is also possible. The finding that FEV1 was one of the independent predictors, in contrast to other studies,15-16 may be explained by the wide range of FEV1 values (0.6-3.2 L) in our patients.

The significance of daytime Sao2 in predicting the nocturnal saturation has been described previously. Bradley et al4 showed that daytime Sao2 and Paco2 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 Sao2 in 97 patients with COPD.5 The definition of a desaturation as a decrease of more than 4% in Sao2 lasting at least five minutes was derived from the study of Block et al7 combined with that of Fletcher et al8 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 al17 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, Sao2, and breathing pattern in patients with COPD. Two studies have shown that mean and lowest Sao2 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 Sao2 was explained by daytime Sao2 and FEV1.

This study was supported by a grant from the Dutch Asthma Foundation.

12 Fletcher EC, Miller J, Divine GW, Fletcher Jr, Milies T. Nocturnal oxyhemoglobin desaturation in COPD patients with arterial oxygen tensions above 60 mm Hg. Chest 1987;92:604-8.