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Coexistence of obstructive sleep apnea and chronic obstructive pulmonary disease

Abstract

Background: Obstructive sleep apnea (OSA) and chronic obstructive pulmonary disease (COPD) may lead to chronic alveolar hypoventilation. The coexistence of OSA and COPD has been termed the 'overlap syndrome'. The aim of the study was to determine the relationship between the severity of COPD and the occurrence of chronic alveolar hypoventilation in patients with OSA and to evaluate the impact of chronic alveolar hypoventilation in patients with the overlap syndrome on the severity of breathing disorders during sleep.

Material and methods: The study included 64 obese patients (BMI 40.0 $\pm$ 6.5 kg/m^2) with OSA (AHI $>$ 15; mean AHI 52 $\pm$ 22) coexisting with COPD. We analysed the results of polysomnography, spirometry and arterial blood gas analysis.

Results: Chronic alveolar hypoventilation was present in 67% of the patients, including 60.5%, 85% and 100% of patients with moderate, severe and very severe COPD by spirometry, respectively. Patients with chronic alveolar hypoventilation had lower values of FVC (2.7 $\pm$ 0.8 l *v.* 3.6 $\pm$ 0.9 l; $p < 0.001$), FEV_1 (1.7 $\pm$ 0.6 l *v.* 2.2 $\pm$ 0.5 l; $p < 0.001$) and mean SaO_2 at the end of obstructive sleep apneas and hypopneas (75% $\pm$ 10% *v.* 84% $\pm$ 5%; $p<0.001$).

Conclusions: Chronic alveolar hypoventilation is observed in the majority of obese patients with moderate to severe OSA and coexisting COPD, including moderate COPD. The occurrence of chronic alveolar hypoventilation in obese patients with OSA coexisting with COPD is associated with a marked arterial hypoxia during obstructive sleep apneic and hypopneic episodes.

Key words: obstructive sleep apnea syndrome, chronic obstructive pulmonary disease, overlap syndrome

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Introduction

The coexistence of obstructive sleep apnea (OSA) and chronic obstructive pulmonary disease (COPD) has been termed the 'overlap syndrome'. This commonly used term was originally proposed by Flenley in 1985 to refer to the concurrent presence of a syndrome caused by repeated episodes of airway obstruction during sleep, or OSA, and of chronic respiratory diseases [1]. Among the patients with the overlap syndrome, Flenley observed mainly COPD patients, formerly referred to as blue bloaters [1].

The overlap syndrome is an important clinical issue, as COPD and OSA are the two chronic respiratory diseases that are most commonly observed in clinical practice [2, 3]. COPD and OSA may both lead to chronic respiratory failure [4, 5]. Although COPD and OSA often coexist, they do not share the same pathogenetic factor [6, 7]. The prevalence of the overlap syndrome in the Polish population of adults over the age of 40 years is 1% [6]. Both COPD and OSA are common in the general population, which is why their coexistence is not such a rare occurrence.

The incidence of OSA in patients with mild COPD is the same as that in the general population [3]. In patients with COPD requiring long-term oxygen therapy the coexistence of moderate to severe OSA has been seen in 16% of the patients [8].

The incidence of COPD in patients with OSA has been estimated by various authors at 9% to 29%

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[5, 6, 9–11]. Bednarek et al. [6] evaluated 76 patients with OSA (with AHI [apnea/hypopnea index] 25.3 ± 16.1) and found COPD to be present in 9.2% of the patients. In a large group of 265 patients with OSA, the overlap syndrome ($FEV_1/FVC = 60\%$) was demonstrated in 11% of the patients [10]. In a group of patients with OSA but without obesity hypoventilation syndrome, the overlap syndrome was present in 19% of the patients [9]. In hospitalised patients with OSA (AHI > 20) the overlap syndrome was demonstrated in 22% of the patients [5]. De Miguel et al. [11] estimated the prevalence of the overlap syndrome in patients referred to hospital due to OSA at 29%.

The coexistence of COPD and OSA is important because in patients with the overlap syndrome the risk of chronic hypercapnic respiratory failure and death due to an exacerbation of COPD is higher than that in patients with "pure" OSA [7, 10, 12–14].

The aim of our study was to determine the relationship between the severity of COPD and the occurrence of chronic alveolar hypoventilation in obese patients with moderate to severe OSA and to evaluate the impact of chronic alveolar hypoventilation on the severity of breathing disorders during sleep.

Material and methods

The study included 64 obese patients admitted to the Department and Clinic of Pulmonology and Lung Cancers, Wroclaw Medical University, Poland, with suspected breathing disorders during sleep. Following a full or limited polysomnography (PSG) they were diagnosed with OSA, and spirometry performed during a stable period of COPD revealed limited ventilatory reserve of the obstructive type. We analysed only those patients whose body mass index (BMI) was 30 kg/m^2 or more, AHI was 15 or more and whose FEV_1/FVC was below 70%.

Nocturnal tests of breathing during sleep were conducted with the use of systems for limited PSG in 39 patients (Poly-MESAM® [MAP, Germany] or EMBLETTA [Resmed, Iceland]) and a system for full PGS (ALVAR [Alvar, France]) in 25 patients. A limited PSG involved the recording of respiratory airflow with a thermistor or a nasal cannula, the recording of respiratory movements of the chest and abdominal wall by plethysmography and the measurement of oxygen saturation in arterial blood (SaO_2) by pulse oximetry. A full PSG involved a simultaneous recording of an encephalogram (C_3A_1 and C_2A_1), a chin electromyogram and an electro-oculogram acquired with surface electrodes. Using these methods and based on the Rechtschaffen and Kales rules, the non-rapid eye movement (NREM) stages were distinguished from the rapid eye movement (REM) stages of sleep [15]. An obstructive apnea was defined as an interruption of respiratory airflow of at least 10 s accompanied by paradoxical, or opposite, respiratory thoracic and abdominal movements. A hypopnea was diagnosed when the amplitude of breathing decreased for at least 10 seconds by at least 50% of the amplitude of the preceding breaths or when the required reduction in amplitude was not present but SaO_2 dropped by at least 3 percentage points or in patients in whom the electrophysiological structure of sleep was recorded until awakening [16].

Limited polysomnograms were first analysed automatically and then edited by the doctor in order to verify or correct the results. In patients who had undergone full polysomnography, differentiation between NREM and REM stages of sleep and the analysis of breathing disorders during these stages were conducted by a doctor.

The frequency of hypopneas and obstructive sleep apneas was calculated and the result was expressed as an AHI value. Moderate OSA was diagnosed when AHI ranged from 15 to 29 and severe OSA was defined as an AHI value equal to or greater than 30. Mean SaO_2 values were calculated from nadir values at the end of hypopneas and sleep apneas. The mean duration of hypopneas and obstructive apneas and the mean duration of the longest hypopneas and obstructive apneas were also calculated.

Spirometry was performed with the LUNGTEST 1000 system (MES, Poland) or Flowscreen (JAEGER, Germany) using the technique conforming to the Polish Respiratory Society guidelines [17]. The measured values were expressed as a percentage of the predicted values developed by the European Community of Steel and Coal (ECSC) and adopted by the European Respiratory Society (ERS) [18].

Spirometry was performed at least 6 weeks after any signs or symptoms that might suggest an exacerbation of COPD. The flow-volume loop was analysed and forced vital capacity (FVC) and forced expiratory volume in 1 second (FEV_1) were measured and expressed in absolute values and as a percentage of the predicted values. The FEV_1/FVC ratio was calculated. If FEV_1/FVC following the administration of a bronchodilator was below 70%, the diagnosis of COPD was made [19].

The following ranges of spirometric values were used when classifying the severity of COPD:

— stage I or mild COPD: $FEV_1/FVC < 70\%$ and $FEV_1 = 80\%$ predicted;
— stage II or moderate COPD: $FEV_1/FVC < 70\%$ and FEV_1 from = 50% to <80% predicted;
— stage III or severe COPD: $FEV_1/FVC < 70\%$ and FEV_1 from = 30% to < 50% predicted;
— stage IV or very severe COPD: $FEV_1/FVC < 70\%$ and $FEV_1 < 30\%$ predicted [19].

Blood gas analyses were performed on arterialised capillary blood collected at rest from awake patients. Hypercapnia was diagnosed when carbon dioxide partial pressure ($PaCO_2$) exceeded 45 mm Hg. Chronic alveolar hypoventilation was diagnosed when hypercapnia persisted during waking hours and was accompanied by elevated HCO_3^- (>27 mmol/l). All the patients underwent a chest X-ray.

The results of clinical assessments are given as means ± standard deviations (SD). All the calculations have been performed with CSS Statistica for Windows version 5.0.

Results

The study population consisted of 58 men and 6 women (6%). The mean age was 52.8 ± 10 years and BMI ranged from 30.9 to 52.8 kg/m^2 (40.0 ± 6.5 kg/m^2). Chest X-rays did not reveal any structural abnormalities of the chest wall or any pathologies within the pleura or the lungs. A total of 34 patients (53%) carried a previous diagnosis of COPD, which was confirmed after admission, while in the remaining 30 patients (47%) the diagnosis of COPD was established during hospitalisation at our Department.

In the entire study population spirometry revealed decreased mean FVC (3059 ± 950 ml, i.e. 71% ± 16% predicted), decreased mean FEV1 (1845 ± 630 ml, i.e. 56% ± 17% predicted) and decreased FEV_1/FVC (62% ± 6%; range: 43–69%). The diagnosis of mild, moderate, severe and very severe COPD was established in 3, 38, 20 and 3 patients (5%, 59%, 31%, 5%), respectively.

Arterial blood gas analysis revealed elevated mean $PaCO_2$ (48.5 ± 8.0 mm Hg) and decreased mean PaO_2 (60.5 ± 10.0 mm Hg). Hypercapnia was observed in 43 patients (67%), while $PaCO_2$ in the remaining 21 patients (33%) was within the normal range. The elevated HCO_3^- (29.2 ± 4.0 mmol/l) indicated chronic hypercapnia, while the mean value of pH (7.40 ± 0.03) was within normal limits. All the patients with hypercapnia were hypoxaemic ($PaO_2 < 70$ mm Hg) and had elevated HCO_3^- (see Table 1 for the mean values of blood gas analysis parameters in patients with and without chronic alveolar hypoventilation).

Chronic hypercapnia was present in 23 patients with moderate COPD (60.5%), 17 patients with severe disease (85%) and all the patients with very severe disease. Overall, chronic hypercapnia was present in 63% of the patients with mild to moderate COPD and in 87% of the patients with severe to very severe disease.

Table 1. The comparison of age, body mass index (BMI) and the results of spirometric and arterial blood gases studies in the patients with obstructive sleep apnea (OSA) syndrome and coexisting chronic obstructive pulmonary disease (COPD) of patients without chronic alveolar hypoventilation ($PaCO_2 < 45$ mm Hg) with chronic alveolar hypoventilation ($PaCO_2 > 45$ mm Hg)

	$PaCO_2 < 45$ mm Hg n = 21	$PaCO_2 > 45$ mm Hg n = 43	p
Age (years)	54 ± 9	52 ± 9	NS
BMI [kg/m^2]	38 ± 9	41 ± 5	NS
$PaCO_2$ [mm Hg]	40 ± 3	53 ± 6	< 0.001
PaO_2 [mm Hg]	69 ± 7	56 ± 9	< 0.001
SaO_2 (%)	93 ± 2	87 ± 6	< 0.001
HCO_3 [mmol/l]	25 ± 2	31 ± 3	< 0.001
pH	7.41 ± 0.04	7.39 ± 0.03	< 0.01
FVC [l]	3.66 ± 0.86	2.75 ± 0.80	< 0.001
FVC (%)	82 ± 6	64 ± 13	< 0.001
FEV_1 [l]	2.22 ± 0.57	1.70 ± 0.57	< 0.001
FEV_1 (%)	65 ± 16	51 ± 14	< 0.001
FEV_1/FVC (%)	63 ± 5	62 ± 7	NS

NS — the difference not statistically significant; FVC — forced vital capacity; FEV_1 — forced expiratory volume in 1 second

Table 2. The comparison of age, body mass index (BMI) and the results of spirometric and arterial blood gases studies in the patients with obstructive sleep apnea (OSA) syndrome and coexisting mild and moderate chronic obstructive pulmonary disease (COPD) (group A) and severe and very severe COPD (group B)

	Group A n = 41	Group B n = 23	p
Age (years)	53 ± 9	52 ± 10	NS
BMI [kg/m^2]	39 ± 7	43 ± 7	NS
$PaCO_2$ [mm Hg]	45 ± 7	56 ± 8	< 0.001
PaO_2 [mm Hg]	65 ± 8	52 ± 9	< 0.001
SaO_2 (%)	92 ± 3	86 ± 6	< 0.001
HCO_3 [mmol/l]	28 ± 3.5	32 ± 4	< 0.01
pH	7.40 ± 0.03	7.38 ± 0.04	< 0.001
FVC [l]	3.48 ± 0.83	2.44 ± 0.56	< 0.001
FVC (%)	79 ± 13	57 ± 12	< 0.001
FEV_1 [l]	2.16 ± 0.53	1.43 ± 0.30	< 0.001
FEV_1 (%)	65 ± 16	51 ± 14	< 0.001
FEV_1/FVC (%)	63 ± 5	62 ± 5	NS

NS — the difference not statistically significant; FVC — forced vital capacity; FEV_1 — forced expiratory volume in 1 second

Table 3. The comparison of the nocturnal polygraphic studies in the patients with obstructive sleep apnea (OSA) syndrome and coexisting mild and moderate chronic obstructive pulmonary disease (COPD) (group A) and severe and very severe COPD (group B)

	Group A n = 41	Group B n = 23	p
AHI	49 ± 19	59 ± 23	NS
Mean SaO_2 at the end of obstructive sleep apneas and hypopneas (%)	79 ± 10	76 ± 9	NS
Minimal SaO_2 at the end of obstructive sleep apneas and hypopneas (%)	58 ± 14	60 ± 17	NS
Mean duration of obstructive sleep apneas and hypopneas (s)	25 ± 9	27 ± 17	NS
Mean duration of the longest obstructive sleep apneas and hypopneas (s)	60 ± 28	56 ± 37	NS

NS — *the difference not statistically significant*; AHI — *apne/hypopne index*

The mean AHI was 52 ± 22 (range: 16–120). Moderate and severe OSA was diagnosed in 10 and 54 patients (16% and 84%), respectively. Mean SaO_2 at the end of obstructive sleep apneas and hypopneas was 78% ± 10% with the nadir at 58% ± 15%. The mean duration of these breathing disorders was 25 ± 11 s, while the mean duration of the longest obstructive sleep apneas and hypopneas was 58 ± 30 s.

Age, BMI, arterial blood gas analysis results, spirometry results and breathing during sleep were compared between the following groups: patients with mild to moderate COPD (Group A) and patients with severe to very severe COPD (Group B) determined by spirometry (Tables 2 and 3). Age and BMI were similar in both groups. Group B showed more severe spirometric abnormalities than Group A with the exception of FEV_1/FVC, which was similar in both groups. Group B also had more severe abnormalities in arterial blood gas analysis than Group A, with higher $PaCO_2$ and HCO_3^- values and lower PaO_2, SaO_2 and pH values. There was no significant differences between the groups in AHI. Despite the initially lower SaO_2 in patients with severe to very severe COPD according to the spirometric classification and the similar duration of obstructive sleep apneas and hypopneas both groups showed a similar decrease in SaO_2.

Age, BMI, arterial blood gas analysis results, spirometry results and breathing during sleep were also compared between the group without chronic alveolar hypoventilation and the group with chronic alveolar hypoventilation (Tables 1 and 4). Age and degree of obesity were similar in both groups. Patients with chronic alveolar hypoventilation showed more severe abnormalities in arterial blood gas analysis (higher $PaCO_2$ and HCO_3^- values

Table 4. The comparison of the nocturnal polygraphic studies in the groups of patients with obstructive sleep apnea (OSA) syndrome coexisting with chronic obstructive pulmonary disease (COPD) without chronic alveolar hypoventilation ($PaCO_2$ < 45 mm Hg) and with chronic alveolar hypoventilation ($PaCO_2$ > 45 mm Hg)

	$PaCO_2$ < 45 mm Hg n = 21	$PaCO_2$ > 45 mm Hg n = 43	p
AHI	45 ± 18	56 ± 22	NS
Mean SaO_2 at the end of obstructive sleep apneas and hypopneas (%)	84 ± 5	75 ± 10	< 0.001
Minimal SaO_2 at the end of obstructive sleep apneas and hypopneas (%)	65 ± 12	54 ± 15	< 0.01
Mean duration of obstructive sleep apneas and hypopneas (s)	25 ± 9	27 ± 12	NS
Mean duration of the longest obstructive sleep apneas and hypopneas (s)	53 ± 19	60 ± 32	NS

AHI — apne/hypopne index; NS — the difference not statistically significant

and lower PaO_2, SaO_2 and pH values). Patients with chronic alveolar hypoventilation also showed more severe spirometric abnormalities with lower FVC and FEV_1 values, although FEV_1/FVC was similar in both groups. AHI and the duration of obstructive sleep apneas and hypopneas were also similar in both groups. The difference in initial SaO_2 between the groups was non-significant, although patients with chronic alveolar hypoventilation showed a greater decrease in SaO_2 during sleep-disordered breathing.

Evaluation of the electrophysiological structure of sleep in 9 patients with chronic alveolar ventilation and 16 patients without chronic alveolar ventilation revealed similar durations of the NREM and REM stages of sleep, expressed as the percentage of total sleep time, with NREM occupying 94% ± 9.7% and 95% ± 6% of total sleep time in patients with and without chronic alveolar ventilation, respectively, and REM occupying 6% ± 9.7% and 5% ± 6.4% of total sleep time in patients with and without chronic alveolar ventilation, respectively.

The relationship between $PaCO_2$ and the severity of COPD is illustrated in Figure 1. The median test, which assessed the relationship between $PaCO_2$ and FEV_1 (% predicted), showed a statistically significant relationship between $PaCO_2$ and the severity of COPD ($\chi^2 = 12.14$; $p < 0.01$).

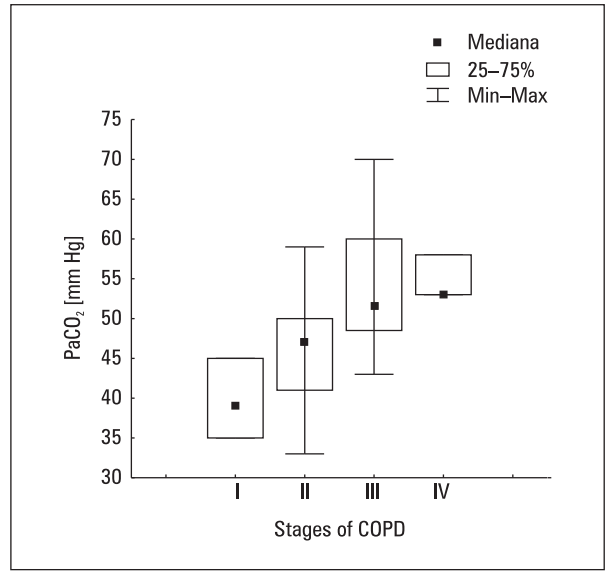

Figure 1. Distribution of $PaCO_2$ related to the severity of chronic obstructive pulmonary disease (COPD)

Table 5 summarises the evaluation of Spearman's rank correlation between FEV_1 (% predicted)

Table 5. The analysis of correlations between forced expiratory volume in 1 second (FEV_1) (% of predicted) parameters related to severity of obstructive sleep apnea (OSA) syndrome in the normocapnic patents and in the hypercapnic severity categories

Correlations of FEV_1 (% of predicted)		AHI		Mean SaO_2 (%)		Minimal SaO_2 (%)	
		R	p	R	p	R	p
$PaCO_2$ [mm Hg]	< 45 (n = 22)	0.259	NS	0.332	NS	0.244	NS
	45–50 (n = 19)	–0.074	NS	0.130	NS	0.020	NS
	51–55 (n = 11)	0.318	NS	0.110	NS	–0.261	NS
	> 55 (n = 12)	–0.696	< 0.05	0.041	NS	0.048	NS

Mean SaO_2 — mean SaO_2 at the end of obstructive sleep apneas and hypopneas; minimal SaO_2 — minimal SaO_2 at the end of obstructive sleep apneas and hypopneas; R — Spearman's rank correlation coefficient; NS — the difference not statistically significant

and such parameters as: AHI, mean SaO_2 and minimal SaO_2 — for normal $PaCO_2$ and for three ranges of hypercapnia: $PaCO_2$ from 45 to 50 mm Hg, from 51 to 55 mm Hg and above 55 mm Hg. This evaluation revealed a negative correlation between FEV_1 and AHI ($p < 0.05$) only in patients with the highest values of $PaCO_2$ (>55 mm Hg).

The evaluation of correlation between $PaCO_2$ and anthropometric parameters, breathing function during sleep and spirometric parameters is summarised in Table 6. $PaCO_2$ was found to correlate with BMI, mean SaO_2, minimal SaO_2, FVC and FEV_1, but not with FEV_1/FVC. Multivariate regression analysis, which assessed the impact of the above parameters, showed significance of FVC [l] ($\beta = -1.07$; $p = 0.0024$) and mean SaO_2 at the end of obstructive sleep apneas and hypopneas ($\beta = -0.40$; $p = 0.0015$). The model we created explained 57.9% of the dependent variable $PaCO_2$. The highest partial correlation coefficient was observed for mean SaO_2 (–0.416). This variable independently explained nearly 9% of the $PaCO_2$ variance.

Table 6. The results of correlation analysis between $PaCO_2$ and anthropometric studies, PSG, and spirometric studies

	$PaCO_2$ correlations	
	R	**p**
Age (years)	–0,010	NS
BMI [kg/m^2]	0,330	< 0,05
AHI	0,107	NS
Mean SaO_2 (%)	–0,579	0,0001
Minimal SaO_2 (%)	–0,383	< 0,01
FVC [l]	–0,584	0,0001
FVC (% of predicted)	–0,535	0,0001
FEV_1 [l]	–0,519	0,0001
FEV_1 (% of predicted)	–0,503	0,0001
FEV_1/FVC (%)	–0,059	NS

Mean SaO_2 — mean SaO_2 at the end of obstructive sleep apneas and hypopneas; minimal SaO_2 — minimal SaO_2 at the end of obstructive sleep apneas and hypopneas; R — Spearman's rank correlation coefficient; NS — the difference not statistically significant; BMI — body mass index; AHI — apne/hypopne index; FVC — forced vital capacity; FEV_1 — forced expiratory volume in 1 second

Discussion

This study of obese patients with moderate to severe OSA with coexistent COPD revealed that most of these patients were experiencing chronic alveolar hypoventilation and only a third of the subjects had no signs of hypercapnia on resting arterial blood gas analysis.

Only in about a half of the patients with the overlap, COPD had been diagnosed and managed before the diagnosis of OSA. Asymptomatic course of COPD in patients with OSA has also been reported by other authors [10, 20]. Our observations indicate that among the obese patients with OSA and a moderate to severe increase in AHI, coexistence of COPD is often associated with chronic alveolar hypoventilation, which in turn suggests an increased risk of severe hypoxaemia during sleep.

Chronic alveolar hypoventilation is not a typical sign of "pure" OSA, in which it most commonly develops if OSA coexists with obesity hypoventilation syndrome [5]. In a previously published study we found that patients with obesity hypoventilation syndrome accounted for as many as 67% of patients with OSA and chronic alveolar hypoventilation and those with coexistent COPD accounted for 33% of patients with OSA and chronic alveolar hypoventilation [5].

Chronic alveolar hypoventilation was observed in the majority of our patients, i.e. in 67% of patients with OSA coexisting with COPD, which is much more than could be expected from the spirometric assessment of COPD severity. Similarly, chronic alveolar hypoventilation in the majority of patients with OSA and coexistent COPD was observed by De Miguel et al. [11], who detected chronic hypercapnia in 60% of the 55 patients with the overlap syndrome (FEV_1/FVC < 70%). A lower prevalence of chronic alveolar hypoventilation among patients with OSA and coexistent COPD was reported by Chaouat et al. [10], who found chronic hypercapnia in 27% of the 30 patients with the overlap syndrome (AHI 64 ± 41, FEV_1/FVC 50% ± 6%). BMI in patients studied by Chaouat et al. was, however, lower (31 ± 5 kg/m^2) than in our patients (40 ± 5.5 kg/^{2}), and obesity is a significant risk factor for chronic alveolar hypoventilation in patients with OSA [2, 5, 9, 21, 22].

Chronic alveolar hypoventilation was not only diagnosed in all the patients in whom spirometry revealed very severe COPD and in nearly all the patients (85%) with spirometric signs of severe COPD, but also in most of the patients (60.5%) with spirometric signs of moderate disease. The statistical analysis confirmed the association between $PaCO_2$ and the severity of COPD.

In stage II or moderate COPD, the mean FEV_1 exceeded 2 L. In "pure" COPD without coexisting sleep disordered breathing, such high FEV_1 values are usually not accompanied by chronic alveolar ventilation and hypercapnia does not generally appear until FEV_1 values remains below 1 L [21–23]. Such low FEV_1 values in our material were observed only in 4 patients: FEV_1 values exceeded 1.5 L in most patients.

FEV_1/FVC in the entire study population was 62% ± 6% and did not differ significantly between hypercapnic and non-hypercapnic patients. No correlation was also found between $PaCO_2$ and FEV_1/FVC. This finding suggests that in obese patients with coexistent COPD bronchial obstruction is not the principal cause of chronic alveolar hypoventilation. This conclusion is confirmed by the result of a recent meta-analysis of 4250 obese patients with OSA, in whom AHI was at least 5. In this group, chronic alveolar hypoventilation was present in 19% of the patients [23]. Factors associated with the development of chronic alveolar hypoventilation turned out to be: reduced FEV_1, reduced vital capacity, reduced total lung capacity, increased BMI and AHI, but not reduced FEV_1/FVC [23].

The multifactorial aetiology of chronic alveolar hypoventilation in patients with OSA coexisting with COPD is further confirmed by studies by Resta et al. [9], who showed in a group of 29 patients with the overlap syndrome that the development of chronic alveolar hypoventilation is associated with increased body mass coexisting with disorders of the ventilatory function of the lungs [9].

Our study included obese patients only, which is probably why we found only a slight difference in BMI between patients with and without alveolar hypoventilation, although we did show a correlation between BMI and $PaCO_2$ in the entire study population.

Patients with chronic alveolar hypoventilation in the course of OSA with coexisting COPD differed from the remaining patients with the overlap syndrome in values of FVC and FEV_1. We also showed a correlation between FVC and $PaCO_2$ and between FEV_1 and $PaCO_2$. However, only in few patients in whom a considerably decreased ventilatory reserve of the lungs had been observed, the occurrence of chronic alveolar hypoventilation could be explained by disordered respiratory mechanics. We found no significant differences in the incidence of breathing disorders during sleep; patients diagnosed with chronic alveolar hypoventilation had higher AHI values than patients without chronic alveolar hypoventilation (55 ± 22 *v.* 45 ± 18), although this difference was not statistically significant ($p = 0.058$).

The very severe breathing disorders during sleep resulted in abnormal electrophysiological sleep structure, as demonstrated by the considerably shortened duration of the REM phase. The percentage contributions of NREM and REM phases during the entire sleep were similar in patients with and without chronic alveolar hypoventilation. Therefore, the development of chronic alveolar hypoventilation was not associated with a shortening or prolongation of the REM phase of sleep.

We found a correlation between $PaCO_2$ and mean SaO_2 obstructive sleep apneas and hypopneas and between $PaCO_2$ and minimum SaO_2 after obstructive sleep apneas and hypopneas. Multivariate regression analysis showed that the most important factor affecting $PaCO_2$ was mean SaO_2 after obstructive sleep apneas and hypopneas. It was also proved that in patients with the overlap syndrome and chronic alveolar hypoventilation, SaO_2 (both mean and minimum) after obstructive sleep apneas and hypopneas was lower than in patients without chronic alveolar hypoventilation. This difference was not observed when we compared the results for the mild-to-moderate COPD group and severe-to-very-severe COPD group despite evident differences in spirometry results.

The considerably severe and repeated episodes of arterial blood hypoxaemia during sleep could have caused the changes in central regulation of breathing, leading to the development of chronic alveolar hypoventilation.

Conclusions

Chronic alveolar hypoventilation occurs in the majority of obese patients with moderate to severe OSA coexisting with COPD, including moderate COPD. The development of chronic alveolar hypoventilation in obese patients with OSA coexisting with COPD depends on the reduction in FVC and FEV_1 and not on the reduction in FEV_1/FVC. The development of chronic alveolar hypoventilation in obese patients with OSA coexisting with COPD is associated with a considerable arterial blood hypoxaemia during obstructive sleep apneas and hypopneas.

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