ORIGINAL ARTICLE

Sleep pattern in patients with Chronic Obstructive Pulmonary Disease and correlation among gasometric, spirometric, and polysomnographic variables

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Objective: *There are few studies on chronic obstructive pulmonary disease (COPD) establishing differences between the functional parameters of the disease and sleep variables. The aim of the study was to describe the sleep pattern of these patients and to correlate spirometric, gasometric and polysomnographic variables.* ***Methods:*** *Transversal study using COPD patients submitted to spirometry, arterial gasometry, and polysomnography.* ***Results:*** *21 male patients were studied with average age = 67 ± 9; 7 ± 4 average points in the Epworth sleepiness scale, average Tiffenau's index (FEV_1/FVC) = 54 ± 13.0%, average PaO_2 = 68 ± 11 mmHg, average $PaCO_2$ = 37 ± 6 mmHg. Sleep efficiency decreased (65 ± 16%) with the reduction of slow wave sleep (8 ± 9%) and rapid eye movement (REM) sleep (15 ± 8%). Average T90 was 43 ± 41%. Average apnea-hypopnea index (AHI) = 3 ± 5/h, where two patients (9.5%) presented obstructive sleep apnea. A significant correlation was observed between PaO_2 and T_{90} ($p < 0.01$), $PaCO_2$ and T_{90} ($p < 0.05$), and AHI and the cardiac rate during REM ($p < 0.01$). A higher number of arousals and stage change was observed. There was no linear correlation between spirometric and polysomnographic variables.* ***Conclusion:*** *Poor sleep quality of these patients was characterized by low sleep efficiency, high number of awakenings and shift of stages. There were no correlations between the spirometric and polysomnographic variables. (**J Pneumol** 2003; 39(2): 69-74)*

Key words – Pulmonary disease, chronic obstructive. Sleep. Polysomnography. Arterial blood gases. Spirometry.

Abbreviations used in the present paper

%@S – Percentage of TST in stages 3 and 4
%S1 – Percentage of TST in stage 1
%S2 – Percentage of TST in stage 2
%SREM – Percentage of TST in REM sleep
%FVC – Percentage of forced vital capacity in regard to predicted value
%FEV_1 – Percentage of forced expiratory volume in the first sec
AHI – Apnea-hypopnea index
Arou – Microarousals
BM – Body movements
CA – Number of central apneas
COPD – Chronic obstructive pulmonary disease
ESS –Epworth Sleepiness Scale
FEV_1 – Forced expiratory volume in the first sec
FEV_1/FVC –Tiffenau's Index
FVC – Forced vital capacity
HO – Hypopnea
Lat – Sleep latency
LatREM – Latency to REM sleep
LM – Leg movements
MA – Number of mixed apneas
NREM – Non rapid eye movement
NREMHR – Heart rate during NREM sleep
OA – Number of obstructive apneas
OSAS – Obstructive sleep apnea syndrome
$PaCO_2$ – Partial CO_2 arterial pressure
PaO_2 – Partial O_2 arterial pressure
REM – Rapid eye movement
REMHR – Heart rate during REM sleep
RFC – Residual Functional Capacity
SC – Stage change
SEf – Sleep Efficiency
SpO_2NREM – Oxygen saturation during non REM sleep
SpO_2REM – Oxygen saturation during REM sleep
T_{90} – Percentage of sleep with hemoglobin saturation under 90%
TRT – Total recording time
Tsnor – Time of snoring
TSP – Total sleep period
TST – Total sleep time

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INTRODUCTION

Several studies demonstrate PaO_2 reduction during sleep in COPD patients[1,2], mainly during REM sleep[3,4], being this decrease more pronounced during the tonic phase of this sleep stage[5]. It is natural to believe that hypoxemia is responsible for sleep fragmentation in COPD, and this hypothesis is supported by experimental studies[6] and in diffuse parenchyma pulmonary disease patients[7,8]. Another hypothesis to explain sleep fragmentation is the hypercapnia, demonstrated in some studies[9,10]; subjects wake up with $PaCO_2$ close to 55 mmHg during NREM sleep and 60 mmHg during REM sleep. Paradoxically, predominantly emphysema patients, usually non-hypercapnic and non-hypoxemic, are the ones who present more sleep fragmentation, suggesting that yet another factor, such as increased ventilatory effort, is responsible for awakening[11].In addition, more hypoxemic individuals present a better sleep pattern, although they can evolve to cardiac arrhythmia[12], right ventricle hypertrophy [13], polycitemia[13,14] and pulmonary hypertension [15]. The correlations between ventilatory functional tests of COPD patients and polysomnographic variables are still little studied. This study has the objective of examining possible correlations among spirometric, gasometric and polysomnographic variables in COPD patients.

METHODS

This is an analytical, transversal type of study, in which patients were included according to the following criteria: history of smoking, productive chronic cough and/or dyspnea, FEV_1/FVC index lower than 70% and irreversibility of bronchodilator spray-induced obstruction. Patients with other clinically or radiologically detectable lung illnesses or who presented any disease that had evolved to organ or system failure were excluded. This study was considered as "minimum risk" in human research[16], and was approved by the Ethics Committee of the University Hospital of Brasília.

After accomplishment of the complete clinical history and physical examination, patients were submitted to arterial gasometry and spyrometry, always in the morning and by the same technician using *Ciba Corning 278 Gas System®* (Ciba Corning, Diagnostics Corp, Medfield – USA) and *Vmax® – 22 series spirometer* (SensorMedics Yorba Linda, Califórnia – USA), respectively.

The whole night polysomnographic recording was performed in the first night the patients slept in the laboratory by two trained and capable technicians, following the specifications and criteria established by Carskadon and Rechtschaffen[17], using *Alice 3®* (Infant and Adult Computorized Polysomnographic System, Geórgia, USA).

The following variables were presented by descriptive statistics: body mass index (BMI), Epworth Sleepiness Scale (ESS), $FEV_1/FVC\%$, PaO_2, $PaCO_2$, total recording time (TRT), total sleep time (TST), sleep latency (Lat), latency to REM sleep (LatREM), snoring time (snorT), body movements (BM), leg movements (LM), changes of stage (CS), percentage of delta sleep (%ΔS), percentage of REM sleep (%REM), percentage of total sleep time in which hemoglobin saturation was below 90% (T_{90}), average heart rate during REM (HRREM) and non-REM (HRNREM) sleep and apnea and hypopnea index (AHI). Linear correlation analysis (Pearson Correlation) was performed among the above mentioned variables. Correlations were considered statistically significant when $p < 0.05$.

RESULTS

Twenty-one male patients with average age = 67.1 ± 8.6 years, BMI = 23.4 ± 3.9 kg/m^2 and smoking index = 74.1 ± 71.7 packs/years, were examined. Their average ESS score = 7.3 ± 4.4.

Mean values of spirometric and gasometric variables were: FVC = 2.85 ± 0.86 L, varying from 1.58 to 4.45 L; % FVC = 84.6 ± 24.0%; FEV_1 = 1.61± 0.75 L, varying from 0.65 to 2.71 L; % FEV_1 = 59.7 ± 27.0%; FVE_1/FVC = 54.1 ± 13.0%, with the lowest being 27% and the highest 69%; PaO_2 = 67.6 ± 10.9 mmHg, varying from 46.8 to 89.2 mmHg; $PaCo_2$ = 37.2 ± 5.5 mmHg, varying from 25.4 to 50.8 mmHg; SaO_2 = 92.5 ± 3.8%.

Mean polysomnographic values are presented in Table 1. Regarding the mean distribution of sleep stages, we observed a high percentage of stage 2 (%S2) = 51.4 ± 8.0% and low percentage of delta sleep (%ΔS) = 8.3 ± 7.7% and of REM sleep (%REMS) = 15.0 ± 8.3% (Table 2).

The mean number of obstructive apneas (AO) was 5.1 ± 12.1 and the mean apnea-hypopnea index (AHI) was 2.9 ± 5.2. Two patients presented AHI higher than 5, representing 9.5% of the sample under study. Hemoglobin saturation during NREM sleep (SpO_2 NREM) varied from 79% to 93%. During REM sleep, mean hemoglobin saturation (SpO_2REM) varied from 72% to 93%. The sample also exhibited a high mean percentage of TST in which hemoglobin saturation lower than 90% (T_{90}) was 43.4 41.2%. The other data are in Table 3.

Regarding the analysis of linear correlation, body mass index (BMI) and the results of the Epworth Sleepiness Scale were not correlated to any demographic, respiratory or polysomnographic variables. Regarding the FEV_1/FVC index, we observed an inverse significant correlation with $PaCO_2$ ($r = -0.45$; $p < 0.05$). In regard to the PaO_2, there was an inverse correlation with T_{90} ($r = -0.76$; $p < 0.01$) (Figure 1). $PaCO_2$ correlated with AHI ($r = -0.39$; $p < 0.05$) (Figure 2) and with T_{90} ($r = 0.47$; $p < 0.05$) (Figure 3). LatREM correlated directly and significantly with SC ($r = 0.50$; $p < 0.05$). %ΔS correlated with BM ($r = -0.40$; $p < 0.05$), with %S1 ($r = -0.71$; $p < 0.05$) and with AHI ($r = -0.41$; $p < 0.05$). AHI was directly and significantly correlated with REMHR ($r = 0.77$; $p < 0.01$) (Figure 4).

TABLE 1
Polysomnographic variables

	TRT (min)	TSP (min)	TST (min)	SEff (%)	Lat (min)	LatREM (min)	Arou (#)	BM (#)	Tsnor (min)	LM (#)	SC (#)
Mean	479.3	436.3	287.3	65.3	35.1	150.1	165.5	38.6	10.3	0.4	133.4
± SD	± 39.1	± 56.6	± 84.9	± 15.6	± 29.2	± 120.9	± 76.6	± 12.9	± 6.0	± 1.0	± 35.8

TABLE 2
Percentage of sleep stages

	%S1 (%)	%S2 (%)	% ΔS (%)	%REM (%)
Mean	23.6	51.4	8.3	15.0
± SD	± 15.8	± 8.0	± 7.7	± 8.3

DISCUSSION

Our patients presented an average age in accordance to the consensus and epidemiological studies in COPD [18,19]. All 21 individuals exhibited smoking as the likely cause of COPD and high pack/year index, characterizing the group as heavy smokers.

With respect to daytime hypersomnolence, the mean score in the Epworth sleepiness index was characterized as non-hypersomnolent; the correlation analysis did not confirm the associations between this index and the other variables studied.

Regarding the spirometric and gasometric values, we observed and important level of upper airways obstruction and discrete hypoxemia without hypercapnia.

Regarding polysomnographic data, our patients' exams were recorded in an ideal time of almost eight hours. However, we realized that the TST was lower than desired, of approximately 4.5 hours, values that are in accordance to the literature [20,21], for healthy individuals in this age range. Our group presented low SEf, considering that this variable in healthy subjects is approximately 80% [22]. We believe that the lower mean was due to the chronic respiratory failure. Regarding the sleep latency, the mean value was slightly above the expected [20]. Our sample showed mean body and leg movements similar to the literature [20] for healthy individuals in the same age range. Therefore, some of our data are concordant with sleep descriptions in healthy subjects in the same age [23]. Nonetheless, we consider that the number of arousals and the number of SC is elevated when compared with subjects in the same age. However, there was no correlation between any of the variables and the daytime somnolence scale in this group.

Considering the distribution of sleep stages, some subjects preserved normal pattern, whereas others presented a reduction of slow wave sleep and of REM sleep. In contrast, there was a proportional increase of sleep stages 1 and 2. Since there is a large variation between normal percentage values and the standard deviation of the sample was large, we may consider that the mean values are within the limits of normality for subjects in this age. However, it must e emphasized that nine patients (43%) did not present sleep stages 3 and 4, and two of them did not present REM sleep, demonstrating the high prevalence of deprivation of these stages in this population.

Regarding the respiratory variables, we found that mean AHI was 2.9 and two patients exhibited an index higher than 5, characterizing OSAHS [24]. Thus, we obtained a 9.5% of the sample with the so-called overlap syndrome or mixed syndrome, an association between COPD and OSAHS. In 1980, Guilleminault and colleagues observed that 85% of 26 COPD patients presented elevated AHI, suggesting that COPD and OSAHS association is common [25]. Different results were published by other authors [26,27].In 1992, Tavares found a prevalence of 11.7% of COPD and OSAHS association in 17 patients and Chaouat and colleagues, in 1995, published a series of 265 COPD patients, where 11% presented mixed syndrome [29]. Therefore, our prevalence of 9.5% is close to more recent data.

TABLE 3
Respiratory variables at the polysomnography

	CA (#)	OA (#)	OH (#)	MA (#)	AHI (#/h)	SpO_2NREM (%)	SpO_2REM (%)	Minimum SpO_2 in apnea (%)	T_{90} (%)
Mean	12.1	5.1	5.2	1.1	2.9	88.6	87.1	82.8	43.4
± SD	± 25.3	± 12.1	± 7.6	± 3.1	± 5.2	± 4.8	± 5.5	± 7.5	± 41.2

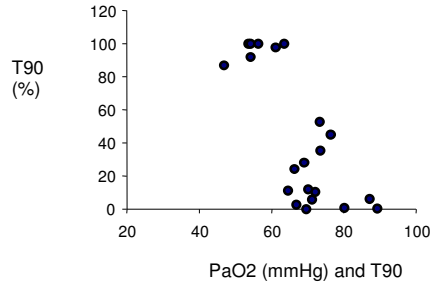

Figure 1 *– Correlation analysis between PaO_2 and T_{90}*

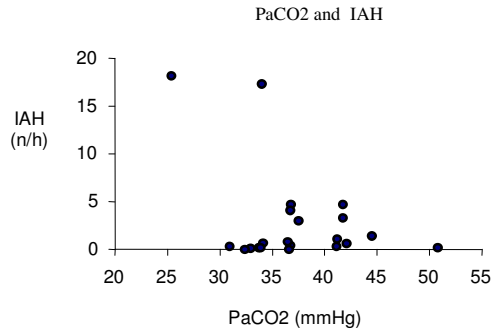

Figure 2 *– Correlation analysis between $PaCO_2$ and AHI*

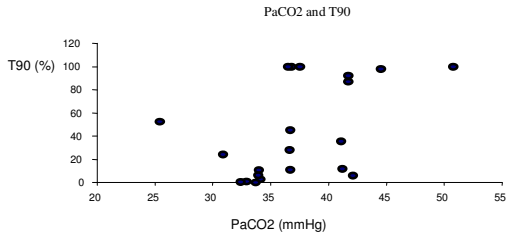

Figure 3 *– Correlation analysis between $PaCO_2$ and T_{90}*

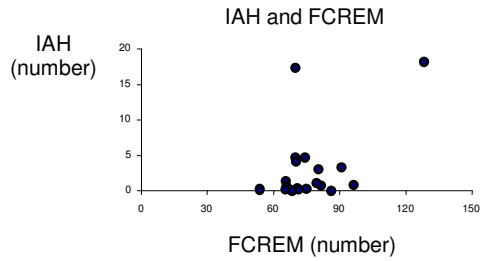

Figure 4 *– Correlation analysis between AHI and REMHR*

Mean hemoglobin saturation of the group was 92.5 ± 3.8%. As known, there is a reduction of ventilation during anybody's sleep [30]. Due to such reduction and to factors inherent of COPD patients, such as the alteration of ventilation/perfusion [26] and the reduction of FRC [31,32], the hemoglobin saturation averages during REM and NREM sleep were lower than 90%. Most of our patients presented high TST, with hemoglobin saturation under 90% (T_{90}), making them more prone to complications due to bad oxygenation [24,33].

Investigation of possible correlations among spirometric, gasometric and polysomnographic variables showed that most of the statistically significant correlations remained within sleep variables, such as percentage of slow wave sleep and REM sleep with body movements and stage changes. That means that the lower the percentage of these stages the highest will be stage change and body movements, characterizing the sleep shallowness in these individuals, which seems natural. Still among polysomnographic variables, an inverse correlation between AHI and %REMS, in accordance with the literature, as in the recent review of the American Sleep Association [34]. But it is between AHI and heart rate during REM sleep that an important correlation happens, demonstrating the well-known post-apnea tachicardia [24,34]. Another established correlation is the level of obstruction, measured by the FEV_1/FVC index and the $PaCO_2$, demonstrating that, the most severe the obstruction the highest the $PaCO_2$ level. These data contradict some authors who concluded that there is no correlation between spirometric and gasometric variables in most of COPD patients [35]. No correlations between spirometric and polysomnographic variables occurred. However, among gasometric variables there were three important correlations: PaO_2 and T_{90}, which is natural, since the lowest the PaO_2 the longest the period of saturation under 90% during TST; $PaCO_2$ and T_{90}, revealing that patients more prone to hypercapnia exhibited longer time of hypoxia during sleep; and $PaCO_2$ and AHI, which, although being significant, may not have a significant biological meaning.

For the group under study, we concluded that mean values of TST, BM, LM, percentage of sleep stages and AHI were normal for this age range; the low SEf and the high number of arousals and SC characterized a major sleep fragmentation in these individuals; the prevalence of mixed syndrome was 9.5%; there was a high percentage of TST with hemoglobin saturation under 90% (T_{90}); PaO_2 and $PaCO_2$ correlated with T_{90}; AHI correlated with REMHR; spirometric and polysomnographic variables did not correlate significantly.

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