Role of oxygen and continuous positive airway pressure therapy in chronic obstructive pulmonary disease patients with nocturnal oxygen desaturation

Randa Salah-Eldin Mohammad[a], Waleed Mohamed El-Sorougi[b], Abeer Salah El-Din Mohamed[a], Laila Anwar Mohamed Zaki[a]

Introduction Sleep has a significant effect on respiration, even in healthy individuals. Breathing difficulties in chronic obstructive pulmonary disease (COPD) patients during sleep are one of the most common symptoms in these patients. Nocturnal desaturation may occur in COPD in the absence of severe daytime hypoxemia. Nocturnal desaturation may contribute to the development of pulmonary hypertension, nocturnal cardiac arrhythmias, and death during sleep. However, the optimal treatment for patients with isolated nocturnal hypoxemia remains uncertain.

Aim of the work The aim of this study was to assess the role of oxygen and continuous positive airway pressure (CPAP) therapy in COPD patients with nocturnal oxygen desaturation (NOD).

Patients and methods This study was conducted on 40 male COPD patients. The included patients were classified into two groups: group 1 included normoxic or mildly hypoxic patients with day time $SpO_2 \geq 91\%$ defined as NOD by fall of greater than 4% from awake SpO_2, and group 2 included moderate and severely hypoxic patients with daytime $SpO_2 \leq 90\%$ who showed a pulse oximetric plot with at least 5 min with $SpO_2 \leq 90\%$ and a peak of $SpO_2 \leq 85\%$ and were considered as nocturnal desaturator. The two groups were subjected to full history taking, clinical examination, the Epworth sleepiness scale, anthropometric measurements, pulmonary function tests (spirometry), radiological examination using chest radiograph, and SpO_2 using pulse oximetry. SpO_2 evaluation using pulse oximetry was carried out for four nights: the first night while breathing room air, the second night while giving low-flow humidified oxygen (2 l/min) overnight, the third night with patients on noninvasive ventilation using autoset CPAP mask, and the fourth night with patients on noninvasive ventilation using autoset CPAP mask with low-flow humidified oxygen (2 l/min).

Results The included patients had moderate, severe, and very severe COPD according to the GOLD spirometric classification. The highest mean value of oxygen saturation was seen in cases that received CPAP with oxygen, followed by cases that received low-flow humidified nasal oxygen, and the lowest mean value was on CPAP. In group 1, there was no significant difference between mean values of oxygen saturation on oxygen and CPAP, but there was a highly significant difference between mean values of oxygen saturation on oxygen and CPAP with oxygen, as well as on CPAP and CPAP with oxygen. In group 2, there was a significant difference between mean values of oxygen saturation on oxygen and CPAP, on nocturnal oxygen and CPAP with oxygen, as well as on CPAP and CPAP with oxygen.

Conclusion In group 1, it is better to prescribe nocturnal CPAP with oxygen than nocturnal oxygen alone or nocturnal CPAP alone to COPD patients with NOD in this group, whereas in group 2 it is better to prescribe nocturnal CPAP with oxygen, followed by nocturnal oxygen alone, compared with nocturnal CPAP alone to COPD patients with NOD in this group.

Egypt J Bronchol 2016 10:266–273

Egyptian Journal of Bronchology 2016 10:266–273

Keywords: chronic obstructive pulmonary disease, continuous positive airway pressure, nocturnal oxygen desaturation

[a]Chest Medicine Department, Faculty of Medicine, Beni-Suef University, Beni-SuefHelwan University, Cairo, [b]Chest Medicine Department, Faculty of Medicine, Beni-Suef Univeristy, Beni-Suef Helwan University, Cairo, Egypt

Correspondence to Waleed Mohamed El-Sorougi, MD, 27 Omar Bakeer St., Saint Fatima Sq., Heliopolis, Cairo 11361, Egypt Tel: +20 100 123 2700; fax: 02 27744055;
e-mail: waleed@sorougi.com

Received 29 April 2016 **Accepted** 28 May 2016

Introduction

Chronic obstructive pulmonary disease (COPD) is a common preventable and treatable disease and is characterized by persistent airflow limitation that is usually progressive and associated with an enhanced chronic inflammatory response in the airways and the lung to noxious particles or gases. Exacerbations and comorbidities contribute to the overall severity in individual patients [1]. Nocturnal oxygen desaturation (NOD) has long been recognized in COPD patients who may spend more than 30% of sleep time with oxygen saturation less than 90% or more than 5% of sleep time below awake SpO_2 mostly during rapid eye movement (REM) sleep [2]. Such nocturnal hypoxemic episodes are usually related to hypoventilation rather than sleeping apnea [3]. Ventilation/perfusion mismatch resulting from progressive airflow limitation and emphysema is the key driver of this hypoxia, which may be exacerbated by sleep and exercise [4]. Awake oxygen saturation has the greatest predictive value, although it imperfectly predicts

 DOI: 10.4103/1687-8426.193637

nocturnal desaturation [5]. Supplemental oxygen is the mainstay of treatment for those with daytime and nocturnal hypoxemia. Noninvasive ventilation has been used as an adjunct to COPD rehabilitation, as it increases ventilation, allows the respiratory muscles to unload during rest and physical exercise, and reduces symptoms of dyspnea [6].

Aim of the work

The aim of this study was to investigate the effect of nocturnal oxygen therapy and continuous positive airway pressure (CPAP) as a treatment of NOD in COPD patients.

Patients and methods

This study was conducted on 40 COPD male patients. The study protocol was approved by local ethical committee and informed consent was taken.

Study design

The included patients were classified into two groups:

Group 1: Normoxic or mildly hypoxic patients with day time $SpO_2 \geq 91\%$ defined as NOD with a fall of greater than 4% from awake baseline.

Group 2: Moderate and severely hypoxic patients with daytime $SpO_2 \leq 90\%$ who showed a pulse oximetric plot with at least 5 min with $SpO_2 \leq 90\%$ and a peak of $SpO_2 \leq 85\%$ were considered as nocturnal desaturators according to Fletcher definition [7].

Inclusion criteria

All patients included in the study fulfilled the criteria of COPD according to the GOLD classification [1].

Exclusion criteria

(1) COPD patients with exacerbation within 4 weeks.
(2) COPD patients with coexisting illness (renal impairment, liver impairment, etc.).
(3) COPD patients with no NOD.

However, we made all possible efforts to exclude individuals with obstructive sleep apnea syndrome (OSAS). *Epworth sleepiness scale*: The patients were asked to evaluate sleepiness (how likely are you to doze off or fall asleep in the following situations) [8]:

(1) Sitting and reading.
(2) Watching television.
(3) Sitting inactive in a public place (e.g. theater).
(4) As a car passenger for an hour without break.
(5) Lying down to rest in the afternoon.
(6) Sitting and talking to someone.
(7) Sitting quietly after lunch without alcohol.
(8) In a car, while stopping for a few minutes in traffic.

The following scale was then used to choose the most appropriate number for each situation:

0=would never doze.
1=slight chance of dozing.
2=moderate chance of dozing.
3=high chance of dozing.

The patients with a total score of 10 or above were considered abnormal and were also excluded. Moreover, all participants who reported snoring were excluded. The history of nonsnoring was taken from bed partners and confirmed by the nurse on duty.

Each patient was subjected to the following:

(1) Full history taking.
(2) Full clinical examination.
(3) Laboratory examination.
(4) Radiological examinations: chest radiograph (posteroanterior and lateral views).
(5) Pulmonary function tests: spirometry was performed using master screen care fusion.
(6) Oxygen saturation measurement using pulse oximetry.Arterial O_2 saturation (SpO_2) was continuously recorded with a pulse oximeter. Measurements were taken during daytime (awake) and the nighttime by positioning the sensor on the second finger of the hand in the supine position. Pulse oximetry was conducted between 10:00 p.m. and 6:00 a.m. for four nights. Close attention was paid to proper fixation of the oxygen sensing device to a patient's finger to ensure stable recording using the transcutaneous pulse oximetry equipment (Rossmax, 11545 Sorrento Valley Rd, Suite 308 San Diego, CA. 92121 USA) model to assess the basic nocturnal oxygen desaturation as these patients were not on a domiciliary oxygen therapy before enrollment.
    (a) The first night while breathing on room air.
    (b) The second night when a low-flow humidified oxygen (2 l/min) overnight was given through nasal prongs. The position of the nasal prongs was checked every hour by a nurse on duty, and on no occasion were prongs found out of place.
    (c) The third night with patients on noninvasive ventilation using autoset CPAP with a full face mask (CPAP).
    (d) The fourth night with patients on noninvasive ventilation using autoset CPAP with a full face mask (CPAP) with low-flow humidified oxygen (2 l/min).
(7) *Noninvasive ventilation*: Noninvasive ventilation was delivered through an autoset – CPAP

device (Ressmed, 3F Iwamotocho Bldg., 3-2-4 Iwamotocho, Chiyoda-ku, Tokyo 101-0032, Japan), which was administered through a comfortably fitting face mask. During noninvasive ventilation, the participants were instructed to relax, breathe calmly, and maintain a respiratory rate similar to spontaneous breathing. During CPAP ventilation, SpO_2 was continuously monitored using portable pulse oximetry and recorded every hour of sleep hours. CPAP device was administered for two nights, one night without supplemental oxygen and the other night with a low-flow humidified oxygen (2 l/min).

Statistical analysis of the results

Data were statistically described in terms of mean±SD, median and range, or frequencies (number of cases) and percentages, when appropriate. Comparison of numerical variables between the study groups was made using the Mann–Whitney *U*-test for independent samples. For comparing categorical data, the χ^2-test was performed. An exact test was used instead when the expected frequency is less than 5. Correlations between different study variables were made using the Spearman Rank correlation test. Accuracy was represented in terms of sensitivity and specificity. *P* values less than 0.05 were considered statistically significant. All statistical calculations were done using computer programs SPSS (Statistical Package for the Social Science; SPSS Inc., Chicago, Illinois, USA) version 21 for Microsoft Windows.

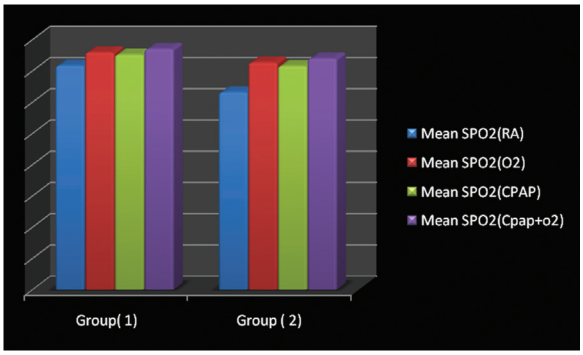
Results

The mean age of patients in group 1 (10 patients) was 63.28 years, and that in group 2 (30 patients) was 64.43 years, and all were male (Table 1).

Comparison between group 1 and group 2 showed a highly statistically significant difference as regards the mean values of nocturnal oxygen saturation on room air, low-flow nasal oxygen, CPAP alone, and CPAP with oxygen. However, Fig. 1 revealed that the highest mean value of nocturnal oxygen saturation in both groups was in cases that received CPAP with oxygen, followed by cases on low-flow nasal oxygen and cases on CPAP, and the lowest mean value was on room air.

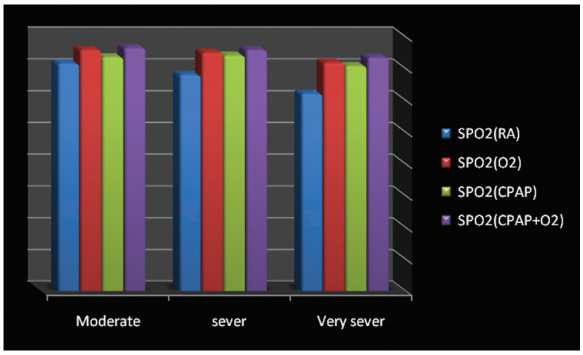
Table 2 and Fig. 2 show that the highest mean value of nocturnal oxygen saturation in moderate, severe, and very severe cases was seen in cases that received CPAP with oxygen, followed by cases on low-flow nasal oxygen followed by cases on CPAP only; moreover, it showed a highly statistically significant difference as regards the mean values of oxygen saturation on room air, low-flow nasal oxygen, and CPAP alone. However, there was a

Figure 1



Comparison between mean values of oxygen saturation on room air, low flow nasal oxygen, continuous positive airway pressure (CPAP) alone, and CPAP with oxygen in group 1 and group 2.

Figure 2



Comparison between the mean values of oxygen saturation on room air, low-flow nasal oxygen, continuous positive airway pressure (CPAP) alone, and CPAP with oxygen in moderate, severe, and very severe stages of chronic obstructive pulmonary disease (COPD).

Table 1 Comparison between group 1 and group 2 as regards mean values of nocturnal oxygen saturation on room air, low-flow humidified nasal oxygen, CPAP alone, and CPAP with oxygen

	Group 1 (n=10) (mean±SD)	Group 2 (n=30) (mean±SD)	P value
Mean SpO_2 (RA)	89.56±1.53	78.87±4.80	<0.001***
Mean SpO_2 (O_2)	94.86±1.46	90.81±3.81	0.002**
Mean SpO_2 (CPAP)	93.92±2.53	89.39±4.26	0.003**
Mean SpO_2 (CPAP+O_2)	96.21±1.54	92.37±3.66	0.003**

CPAP, continuous positive airway pressure; RA, room air. $P \geq 0.05$ (nonsignificant). *$P<0.05$ (significant). **$P<0.01$ (highly significant). ***$P<0.001$ (extremely significant).

Table 2 Comparison between moderate (three patients), severe (17 patients), and very severe (20 patients) stages of COPD as regards mean values of nocturnal oxygen saturation on room air, low-flow humidified nasal oxygen, CPAP alone, and CPAP with oxygen

	Moderate (*n*=3) (mean±SD)	Severe (*n*=17) (mean±SD)	Very severe (*n*=20) (mean±SD)	*P* value
Mean SpO_2 (RA)	89.50±3.71	85.02±4.97	77.61±4.93	<0.001***
Mean SpO_2 (O_2)	94.87±2.12	93.74±2.36	89.79±3.96	0.002**
Mean SpO_2 (CPAP)	92.0±5.30	92.63±3.49	88.48±4.21	0.009**
Mean SpO_2 (CPAP+O_2)	95.56±0.61	94.80±3.05	91.78±3.74	0.022*

COPD, chronic obstructive pulmonary disease; CPAP, continuous positive airway pressure; RA, room air. $P\geq0.05$ (nonsignificant). $^*P<0.05$ (significant). $^{**}P<0.01$ (highly significant). $^{***}P<0.001$ (extremely significant).

Table 3 Comparison between mean values of nocturnal oxygen saturation on nocturnal low-flow humidified nasal oxygen and nocturnal CPAP, mean values of nocturnal oxygen saturation on nocturnal low-flow humidified nasal oxygen and nocturnal CPAP with oxygen, and mean values of nocturnal oxygen saturation on nocturnal CPAP and nocturnal CPAP with oxygen in group 1 and group 2

Groups	O_2 and CPAP	O_2 and CPAP+O_2	CPAP and CPAP+O_2
Group 1			
N	10	10	10
r-Coefficient	0.750	0.701	0.679
P value	0.122	0.005**	0.004**
Group 2			
N	30	30	30
r-Coefficient	0.570	0.487	0.761
P value	0.041*	0.033*	<0.001***

CPAP, continuous positive airway pressure. $P\geq0.05$ (nonsignificant). $^*P<0.05$ (significant). $^{**}P<0.01$ (highly significant). $^{***}P<0.001$ (extremely significant).

significant difference between mean values of oxygen saturation on CPAP with oxygen in moderate, severe, and very severe stages of COPD (Table 3).

Group 1

(1) There was no significant difference between mean values of nocturnal oxygen saturation on nocturnal oxygen and nocturnal CPAP.
(2) However, there was a highly significant difference between mean values of nocturnal oxygen saturation on nocturnal oxygen and nocturnal CPAP with oxygen. Moreover, there was a highly significant difference between mean values of nocturnal oxygen saturation on nocturnal CPAP and nocturnal CPAP with oxygen.

Group 2

(1) There was a significant difference between mean values of nocturnal oxygen saturation on nocturnal oxygen and nocturnal CPAP. Moreover, there was a significant difference between mean values of nocturnal oxygen saturation on nocturnal oxygen and nocturnal CPAP with oxygen.
(2) Moreover, there was an extremely significant difference between the mean values of nocturnal oxygen saturation on nocturnal CPAP and nocturnal CPAP with oxygen (Table 4).

Very severe stage

(1) There was no significant difference between the mean values of nocturnal oxygen saturation on nocturnal oxygen and nocturnal CPAP.
(2) However, there was a significant difference between the mean values of nocturnal oxygen saturation on nocturnal oxygen and nocturnal CPAP with oxygen.
(3) Moreover, there was an extremely significant difference between mean values of nocturnal oxygen saturation on nocturnal CPAP and nocturnal CPAP with oxygen.

Severe stage

(1) There was no significant difference between the mean values of nocturnal oxygen saturation on nocturnal oxygen and nocturnal CPAP, or between mean values of nocturnal oxygen saturation on nocturnal oxygen and nocturnal CPAP with oxygen.
(2) However, there was a highly significant difference between the mean values of nocturnal oxygen saturation on nocturnal CPAP and nocturnal CPAP with oxygen.

Moderate stage

(1) There was no significant difference between the mean values of oxygen saturation on nocturnal oxygen and nocturnal CPAP or between the mean values of oxygen saturation on nocturnal oxygen and nocturnal CPAP with oxygen, or

Table 4 Comparison between mean values of nocturnal oxygen saturation on nocturnal low-flow humidified nasal oxygen and nocturnal CPAP, mean values of nocturnal oxygen saturation on nocturnal low-flow humidified nasal oxygen and nocturnal CPAP with oxygen, mean values of nocturnal oxygen saturation on nocturnal CPAP and nocturnal CPAP with oxygen in very severe, severe, and moderate stages of COPD

	O_2 and CPAP	O_2 and CPAP+O_2	CPAP and CPAP+O_2
Very severe (*n*=20)			
r-Coefficient	0.474	0.473	0.764
P value	0.178	0.037*	<0.001***
Severe (*n*=17)			
r-Coefficient	0.734	0.531	0.781
P value	0.064	0.113	0.001**
Moderate (*n*=3)			
r-Coefficient	1.000	1.000	1.000
P value	0.423	0.634	0.634

COPD, chronic obstructive pulmonary disease; CPAP, continuous positive airway pressure. $P \geq 0.05$ (nonsignificant). *$P<0.05$ (significant). **$P<0.01$ (highly significant). ***$P<0.001$ (extremely significant).

between the mean values of oxygen saturation on nocturnal CPAP and nocturnal CPAP with oxygen.

Group 1

As regards FVC% pred, there was a positive correlation with mean values of oxygen saturation on low-flow nasal oxygen, whereas there was a negative correlation with mean values of oxygen saturation on room air, CPAP alone, and CPAP with oxygen. As regards FEV_1% pred, there was a positive correlation with mean values of oxygen saturation on room air and low-flow nasal oxygen, whereas there was a negative correlation with mean values of oxygen saturation on CPAP alone and CPAP with oxygen.

As regards FEV_1/FVC, there was a positive correlation, with mean values of oxygen saturation on room air, low-flow nasal oxygen, and CPAP with oxygen, whereas there was a negative correlation with mean values of oxygen saturation on CPAP alone.

Group 2

As regards FVC% pred, there was a positive correlation with mean values of oxygen saturation on room air, low-flow nasal oxygen, CPAP alone, and CPAP with oxygen. Moreover, as regards FEV_1% pred, there was a positive correlation with mean values of oxygen saturation on room air and low-flow nasal oxygen CPAP alone, and CPAP with oxygen.

As regards FEV_1/FVC, there was a positive correlation with mean values of oxygen saturation on room air and CPAP with oxygen, whereas there was a negative correlation with mean values of oxygen saturation on low-flow nasal oxygen and CPAP alone.

Discussion

It is well known that people with normal lungs can desaturate during sleep [9]. More than 75% of patients with COPD report poor sleep quality, night-time symptoms, and sleep disturbances, which are generally not considered in the clinical management of the disease [10]. Breathing difficulties in COPD patients during sleep are the most common symptoms after dyspnea and fatigue [11]. Multiple mechanisms may contribute to nocturnal hypoxia, including alterations in ventilation perfusion [12], reduced functional residual capacity, reduced respiratory drive, and alveolar hypoventilation [13] possibly as a consequence of intercostal muscle hypotonia [7]. Nocturnal hypoxemia in COPD patients is characterized by bad quality of sleep; these episodes cause an increase in pulmonary arterial pressure, arrhythmias, and in the long-term they are responsible for reduced survival [14]. Nocturnal desaturation may occur in COPD in the absence of severe daytime hypoxemia. The prevalence of such ‘isolated’ nocturnal desaturation has previously been reported [15].

Valipour *et al*. [15] reported that, even in the absence of significant awake hypoxemia, nocturnal hypoxemia occurs, and furthermore it contributes to the development of pulmonary hypertension; this is in agreement with our study results in group 1. Moreover, they confirmed that patients with COPD who are hypoxemic during wakefulness become more hypoxemic during sleep as in group 2 of our study, and they reported that this hypoxemia also causes a reduction in the amount and quality of sleep in COPD patients compared with healthy controls.

In this study, the results are in agreement with those of Lewis *et al*. [16], who studied the prevalence of isolated nocturnal desaturation in COPD. They found that significant nocturnal desaturation was common in patients with mild-to-moderate daytime hypoxemia (PaO_2=56–70 mmHg) and that patients with resting saturations of less than 95% had the worst level of nocturnal oxygen saturation. This is in agreement with our findings, in which group 2 (moderate and severely hypoxic patients) had a lower level of nocturnal oxygen saturation compared with group 1 (normoxemic or mildly hypoxic).

Kinsman *et al.* [17] reported that the NOD in COPD patients is determined by the daytime arterial saturation. This is not in agreement with our study, as we found that patients with normal daytime arterial oxygen saturation desaturate at night and were diagnosed as nocturnal desaturators. Lacasse *et al.* [18] found that a significant proportion (38%) of patients with moderate-to-severe COPD who do not qualify for home oxygen therapy based on their daytime PaO_2 have NOD without evidence of sleep apnea, which is also supporting our results.

In 70 hospitalized patients affected by COPD, night pulse oximetry was performed by De Angelis *et al.* [19]; they found that 54 (77.15%) of them were night desaturators (NOD), whereas 16 (22.85%) were not desaturators. The night desaturators had a FEV_1% pred of 37±16, but it was found that only patients with FEV_1 less than 49% resulted to desaturate, which is not matching our study. This difference in result can be attributed to the wide range of FEV_1 (moderate, severe, and very severe) we studied. FEV_1 values were found to be 39±10 in group 1 and 27±8 in group 2.

Fleetham *et al.* [20] reported that COPD patients with mean FEV_1 less than 26% were night desaturators. This result is not in agreement with our results, as above and below these values patients were desaturators, as in our study the mean FEV_1% pred in group 1 was 39.20±10 and that in group 2 was 27.70±8. Eugene *et al.* [21], in their study on 37 patients (27%) of the remaining 135 COPD patients with arterial oxygen tensions above 60 mmHg, showed nocturnal oxyhemoglobin desaturation in normoxemic patients, as in group 1 of this study.

Correlation of spirometric values with nocturnal oxygen saturation in group 1 is presented in Table 5. As regards FVC% pred, there was a positive correlation with mean values of nocturnal oxygen saturation on nocturnal
low-flow nasal oxygen, whereas there was a negative correlation with mean values of nocturnal oxygen saturation on room air, nocturnal CPAP only, and nocturnal CPAP with oxygen. However, as regards FEV_1% pred there was a positive correlation with mean values of nocturnal oxygen saturation on room air and nocturnal low-flow nasal oxygen, whereas there was a negative correlation with mean values of nocturnal oxygen saturation on nocturnal CPAP only and nocturnal CPAP with oxygen. As regards FEV_1/FVC, there was a positive correlation with mean values of nocturnal oxygen saturation on room air, nocturnal low-flow nasal oxygen, and nocturnal CPAP with oxygen, whereas there was a negative correlation with mean values of nocturnal oxygen saturation on CPAP only. Correlation of these values with nocturnal oxygen saturation in group 2 is presented in Table 6. As regards FVC% pred, there was a positive correlation with mean values of nocturnal oxygen saturation on room air, nocturnal low flow nasal oxygen, nocturnal CPAP only, and nocturnal CPAP with oxygen. Moreover, as regards FEV_1% pred, there was a positive correlation with mean values of nocturnal oxygen saturation on room air and nocturnal low-flow nasal oxygen, nocturnal CPAP only, and nocturnal CPAP with oxygen.

Table 5 Correlation between mean values of nocturnal oxygen saturation on room air, low-flow humidified nasal oxygen, CPAP alone, and CPAP with oxygen saturation in different spirometric parameters (FVC – FEV_1–FEV_1/FVC) in group 1

Group 1	FVC% pred		FEV_1% pred		FEV_1/FVC	
Mean SpO_2 (RA)						
r-Coefficient	–0.189	Negative	0.009	Positive	0.181	Positive
P value	0.602		0.981		0.616	
Mean SpO_2 (O_2)						
r-Coefficient	0.086	Positive	0.159	Positive	0.108	Positive
P value	0.812		0.662		0.766	
Mean SpO_2 (CPAP)						
r-Coefficient	–0.143	Negative	–0.299	Negative	–0.120	Negative
P value	0.694		0.402		0.742	
Mean SpO_2 (CPAP+O_2)						
r-Coefficient	–0.335	Negative	–0.071	Negative	0.165	Positive
P value	0.344		0.846		0.648	

CPAP, continuous positive airway pressure; RA, room air.

Table 6 Correlation between mean values of nocturnal oxygen saturation on room air, low flow nasal oxygen, CPAP alone, and CPAP with and different spirometric parameters (FVC% pred – FEV_1% pred – FEV_1/FVC oxygen) in group 2

Group 2	FVC% pred		FEV_1% pred		FEV_1/FVC	
Mean SpO_2 (RA)						
r-Coefficient	0.354	Positive	0.475	Positive	0.051	Positive
P value	0.055		0.008		0.789	
Mean SpO_2 (O_2)						
r-Coefficient	0.415	Positive	0.294	Positive	−0.252	Negative
P value	0.023		0.115		0.179	
Mean SpO_2 (CPAP)						
r-Coefficient	0.293	Positive	0.260	Positive	−0.078	Negative
P value	0.116		0.165		0.681	
Mean SpO_2 (CPAP+O_2)						
r-Coefficient	0.196	Positive	0.282	Positive	0.016	Positive
P value	0.299		0.132		0.932	

CPAP, continuous positive airway pressure; RA, room air.

However, as regards FEV_1/FVC, there was a positive correlation with mean values of nocturnal oxygen saturation on room air and nocturnal CPAP with oxygen, whereas there was a negative correlation with mean values of oxygen saturation on nocturnal low flow nasal oxygen and nocturnal CPAP only.

Zanchet and Viegas [22] found that there was a positive and significant correlation between the FEV_1/FVC ratio (%) and SpO_2 during sleep on room air in COPD patients with nocturnal desaturation.

Bradley *et al*. [23] studied COPD patients who were not hypoxemic while awake, who showed nocturnal hypoxemia with a significant drop from baseline awake SpO_2. Baseline awake SpO_2 correlated well with mean nocturnal SpO_2; moreover, they confirmed that FEV_1 had a positive correlation with mean nocturnal SpO_2. Chaouat *et al*. [24] found that nocturnal desaturators had a lower FEV_1/FVC ratio (P=0.04) and lower FEV_1 in agreement with our study (but the difference was not statistically significant).

De Angelis *et al*. [19] confirmed a significant correlation between FEV_1 and mean nocturnal SpO_2% (the worse the FEV_1, the lower the mean nocturnal SpO_2%). This is in agreement with our study as they demonstrated that the more the respiratory function is impaired, the more likely these individuals will be night-time hypoxemic.

Conclusion and recommendations

In group 1, there was no significant difference between mean values of oxygen saturation on nocturnal oxygen and nocturnal CPAP, and hence it is equal to prescribe each of them to COPD patients with NOD in this group. Moreover, there was a highly significant difference between mean values of oxygen saturation on nocturnal oxygen and nocturnal CPAP with oxygen, and hence it is better to prescribe nocturnal CPAP with oxygen than nocturnal oxygen to COPD patients with NOD in this group. Moreover, there was a highly significant difference between mean values of oxygen saturation on nocturnal CPAP and nocturnal CPAP with oxygen, and hence it is better to prescribe nocturnal CPAP with oxygen than nocturnal CPAP alone to COPD patients with NOD in this group. As regards patients in group 2, there was a significant difference between the mean values of oxygen saturation on nocturnal oxygen and nocturnal CPAP, and hence it is better to prescribe nocturnal oxygen than nocturnal CPAP alone to COPD patients with NOD in this group. Moreover, there was a significant difference between mean values of oxygen saturation on nocturnal oxygen and nocturnal CPAP with oxygen, and hence it is better to prescribe nocturnal CPAP with oxygen than nocturnal oxygen to COPD patients with NOD in this group. Moreover, there was an extremely significant difference between mean values of oxygen saturation on nocturnal CPAP and nocturnal CPAP with oxygen, and hence it is better to prescribe nocturnal CPAP with oxygen than nocturnal CPAP alone to COPD patients with NOD in this group.

Patients with very severe pulmonary function tests showed no significant difference between mean values of oxygen saturation on nocturnal oxygen and nocturnal CPAP, and hence it is equal to prescribe each of them to COPD patients with NOD in this stage. Moreover, there was a significant difference between mean values of oxygen saturation on nocturnal oxygen and nocturnal CPAP with oxygen, and so it is better to prescribe nocturnal CPAP with oxygen than nocturnal oxygen to COPD patients with NOD in this group. Moreover, there was an extremely significant difference between mean values of oxygen saturation on nocturnal CPAP and nocturnal CPAP with oxygen, and hence it is better to prescribe nocturnal CPAP with oxygen than nocturnal CPAP alone to COPD patients with NOD in this stage. However, in severe cases there was no significant difference between mean values of oxygen saturation on nocturnal oxygen and nocturnal CPAP, and hence it is equal to prescribe each of them to COPD patients with NOD in this stage. Moreover, there was no significant difference between mean values of oxygen saturation on nocturnal oxygen and nocturnal CPAP with oxygen, and so it is equal to prescribe each of them to COPD patients with NOD in this stage. Moreover, there was a highly significant difference between mean values of oxygen saturation on nocturnal CPAP and nocturnal CPAP with oxygen, and hence it is better to prescribe nocturnal CPAP with oxygen than nocturnal CPAP alone to COPD patients with NOD in this stage. In moderate cases there was no significant difference between mean values of oxygen saturation on nocturnal oxygen and nocturnal CPAP, and so it is equal to prescribe each of them to COPD patients with NOD in this stage. There was no significant difference between mean values of oxygen saturation on nocturnal oxygen and nocturnal CPAP with oxygen, and thus it is equal to prescribe each of them to COPD patients with NOD in this stage. Moreover, there was no significant difference between mean values of oxygen saturation on nocturnal CPAP and nocturnal CPAP with oxygen, and hence it is equal to prescribe each of them to COPD patients with NOD in this stage.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1 Global Initiative for Chronic Obstructive Lung Disease. *Global strategy for the diagnosis, management and prevention of chronic obstructive pulmonary disease*. NHLBI/WHO Global Initiative for Chronic Obstructive Lung Disease (GOLD 2014)

2 Becker HF, Piper AJ, Flynn WE, McNamara SG, Grunstien RR, Peter JH, Breathing during sleep in patients with nocturnal desaturation. *Am J Resp Crit Care Med* 1999; **159**:112–118.

3 Hudgel DW, Martin RJ, Capehart M, Johnson B, Hill P. Contribution of hypoventilation to sleep oxygen desaturation in chronic obstructive pulmonary disease. *J Appl Physiol Respir Environ Exerc Physiol* 1983; **55**:669–677.

4 Brian DK, Patrcik DM, Walter TM. Hypoxamia in patients with COPD causes, effect and disease progression. *Int J Chronic Obstruct Pulm Dis* 2011; **6**:199–208.

5 Krachman S, Minai OA, Scharf SM. Sleep abnormalities and treatment in emphysema. *Proc Am Thorac Soc* 2008; **5**:536–542.

6 Highcock M, Shneerson J, Smith I. Increased ventilation with NIPPV does not necessarily improve exercise capacity in COPD. *Eur Respir J* 2003; **22**:100–105.

7 Fletcher EC, Donner CF, Midgren B, Zielinski J, Levi-Valensi P, Braghiroli A, Survival in COPD patients with a daytime PaO_2 greater than 60 mmHg with and without nocturnal oxyhemoglobin desaturation. *Chest* 1992; **101**:649–655.

8 Johns MW. A new method for measuring daytime sleepiness: the Epworth sleepiness scale. *Sleep* 1991; **14**:540–545.

9 Tiep BL. Long-term home oxygen therapy. *Clin Chest Med* 1990; **11**:505–521.

10 Agusti A, Hedner J, Marin JM, Barbé F, Cazzola M, Rennard S. Night-time symptoms: a forgotten dimension of COPD. *Eur Respir Rev* 2011; **20**:183–194.

11 Klink ME, Dodge R, Quan SF. The relation of sleep complaints to respiratory symptoms in a general population. *Chest* 1994; **105**:151–154.

12 Douglas NJ, Flenley DC. Breathing during sleep in patients with obstructive lung disease. *Am Rev Respir Dis* 1990; **141**(Pt 1):1055–1070.

13 Millman RP, Kramer NR. Sleep disorders and outpatient treatment of patients with pulmonary disease. *Curr Opin Pulm Med* 1996; **2**:507–512.

14 McNicholas WT. Impact of sleep in COPD. *Chest* 2000; **117** (Suppl):48S–53S.

15 Valipour A, Lavie P, Lothaller H, Mikulic I, Burghuber OC. Sleep profile and symptoms of sleep disorders in patients with stable mild to moderate chronic obstructive pulmonary disease. *Sleep Med* 2011; **12**:367–372.

16 Lewis CA, Fergusson W, Eaton T, Zeng I, Kolbe J. Isolated nocturnal desaturation in COPD: prevalence and impact on quality of life and sleep. *Thorax* 2009; **64**:133–138.

17 Kinsman RA, Yaroush RA, Fernandez E, Dirks JF, Schocket M, Fukuhara J Symptoms and experiences in chronic bronchitis and emphysema. *Chest* 1983; **83**:755–761.

18 Lacasse Y, Sériès F, Vujovic-Zotovic N, Goldstein R, Bourbeau J, Lecours R, Evaluating nocturnal oxygen desaturation in COPD – revised. *Respir Med* 2011; **105**:1331–1337.

19 De angelis G, Sposato B, Mazzei L, Giocondi F, Sbrocca A, Predictive indexes of nocturnal desaturationin COPD patients not treated with long term oxygen therapy. *Eur Rev Med Pharmacol Sci* 2001; **5**:173–179.

20 Fleetham JA, Mezon B, West P, Bradley CA, Anthonisen NR, Kryger MH Chemical control of ventilation and sleep arterial oxygen desaturation in patients with COPD. *Am Rev Respir Dis* 1980; **122**:583–589.

21 Eugene F, Joanna M, George W, Joyce G, Miller T. Nocturnal oxy hemoglobin desaturation in COPD patients with arterial oxygen tensions above 60 mm Hg. *Chest* 1987; **92**:604–608.

22 Zanchet RC, Viegas CA. Nocturnal desaturation: predictors and the effect on sleep patterns in patients with chronic obstructive pulmonary disease and concomitant mild daytime hypoxemia. *J Bras Pneumol* 2006; **32**:207–212.

23 Bradley TD, Mateika J, Li D, Avendano M, Goldstein RS. Daytime hypercapnia in the development of nocturnal hypoxemia in COPD. *Chest* 1990; **97**:308–312

24 Chaouat A, Weitzenblum E, Kessler R, Charpentier C, Ehrhart M, Levi-Valensi P, Sleep-related O_2 desaturation and daytime pulmonary haemodynamics in COPD patients with mild hypoxaemia. *Eur Respir J* 1997; **10**:1730–1735.