Home Overnight Pulse Oximetry in Patients With COPD*  
More Than One Recording May Be Needed

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Study objectives: Home overnight pulse oximetry (OPO) is used to assess nocturnal desaturation in patients with COPD, but the current practice of relying on one recording has not been studied. We assessed the variability of nocturnal desaturation in patients with COPD between nights, as measured by home OPO.

Design: Study subjects attended for clinical evaluation, spirometry, and arterial blood gas analysis. OPO was prospectively completed at home on 2 consecutive nights (study night 1 [N1] and study night 2 [N2]) and repeated at 3 weeks (study night 3 [N3]).

Setting: Respiratory Services, Green Lane Hospital, Auckland, New Zealand.

Patients: Twenty-six patients with clinically stable COPD (mean age, 69.3 years [SD, 6.9]; FEV1, 28.6% predicted [SD, 10.6]; PO2, 71.3 mm Hg [SD, 9.8]). Patients with asthma or clinical evidence of obstructive sleep apnea were excluded.

Measurements and results: Mean nocturnal saturation (MNS) and time spent with saturation below 90% (TB90%) were calculated for N1, N2, and N3. Group mean recording length, MNS, and TB90% were similar for each night. Little variation in MNS was seen between nights (N1 and N2 mean difference, 1.31%; N2 and N3, 1.26%; N1 and N3, 1.25%). Larger variation was seen between nights for TB90% (N1 and N2 mean difference, 17.46%; N2 and N3, 9.95%; N1 and N3, 14.05%). No factors were identified that predicted increased variability of TB90%. Using the current definition of “significant nocturnal desaturation” (TB90% > 30% of the night), 9 of 26 patients (34.6%) changed category between “desaturator” and “nondesaturator” from N1 to N2.

Conclusion: Nocturnal desaturation in patients with COPD exhibits considerable night-to-night variability when measured by home OPO. A single home OPO recording may be insufficient for accurate assessment of nocturnal desaturation.

Key words: COPD; nocturnal desaturation; oximetry; reproducibility

Abbreviations: MNS = mean nocturnal saturation; N1 = study night 1; N2 = study night 2; N3 = study night 3; OPO = overnight pulse oximetry; OSA = obstructive sleep apnea; REM = rapid eye movement; TB90% = time spent with a saturation below 90%

Many patients with COPD exhibit nocturnal desaturation.1,2 The reported prevalence of “significant nocturnal desaturation” in patients with COPD with only mild-to-moderate daytime hypoxemia has varied between 25% and 70%.3–5 In part, this is due to the lack of a universally accepted definition of significant nocturnal desaturation. In the United Kingdom and Europe, desaturation below 90% for > 30% of the night has gained widespread acceptance as defining significant nocturnal desaturation, both in research5,6 and for the purpose of oxygen prescription.7 However, in the United States, nocturnal oxygen therapy is advocated for nocturnal desaturation that is less rigidly defined.8 Prescription of nocturnal oxygen therapy remains

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widespread, although the efficacy of such therapy in preventing adverse outcomes has recently been questioned.6

Statistically significant relationships exist between nocturnal desaturation and daytime hypoxemia, hypercarbia, and exercise desaturation, but are of insufficient strength to allow accurate prediction of nocturnal desaturation. Thus, in clinical practice, nocturnal desaturation is directly assessed using overnight pulse oximetry (OPO). This is usually carried out in the home setting, on 1 night only. The results form the basis of clinical decision making, most often and importantly the prescription of nocturnal oxygen. Most previous studies of nocturnal desaturation have employed OPO in the sleep laboratory setting combined with polysomnography. The hospital setting was used in the only two studies that have assessed OPO on repeated nights, but neither study investigated the variability between nights of the time spent with a saturation below 90% (TB90%). It has recently been shown that compared to oximetry alone, the presence of polysomnography monitoring equipment and an unfamiliar environment caused underestimation of the severity of nocturnal hypoxemia as measured by TB90%. The authors subsequently suggested that home OPO should be the “method of choice” for evaluating nocturnal hypoxemia.

There are no published studies assessing the variability of home OPO between nights; therefore, we aimed to determine the variability of nocturnal desaturation in COPD as measured by home OPO recordings, both night-to-night and over a period of 3 weeks of clinical stability. We also assessed the impact that the variability may have on clinical decision making.

Materials and Methods

Subjects

Subjects were recruited from outpatient services at Green Lane Hospital, Auckland, New Zealand. Eligible patients had moderate-to-severe COPD defined clinically and physiologically according to British Thoracic Society criteria. Subjects had to be in clinically stable condition with no exacerbation for at least 4 weeks. Exacerbation was defined as per the Inhaled Steroids in Obstructive Lung Disease in Europe study, as a deterioration in respiratory symptoms that required treatment with oral corticosteroids or antibiotics. Exclusion criteria were history of asthma or primary respiratory disorder other than COPD, unstable comorbidity, use of nocturnal oxygen therapy, or clinical suspicion of obstructive sleep apnea (OSA). The latter was defined as a sleep history of snoring, witnessed apneas, and excessive daytime somnolence assessed by the Epworth sleepiness scale. Written informed consent was obtained from all participants and the study was approved by the Auckland Ethics Committee.

Study Design and Measurements

Demographics, history, and body mass index were recorded. Arterial blood gas samples were drawn on room air in the sitting position following 30 min of rest. Subsequently, prebronchodilator spirometry was performed according to American Thoracic Society standards using a Microloop portable spirometer (Micro Medical Ltd; Kent, UK) and repeated 15 min after two inhalations of salbutamol via large-volume spacer. The best of three readings for both FEV1 and FVC were recorded, and expressed in liters and percentage of predicted normal using the European Community Coal and Steel data set. The Pittsburgh sleep quality index was completed to assess subjective sleep quality. This is a self-administered questionnaire giving a composite score out of 21; a score > 5 has been shown to accurately identify “poor” sleepers.

Home OPO

OPO was carried out on the following 2 nights (study night 1 [N1] and study night 2 [N2]). Three weeks later, subjects were reassessed for evidence of intervening exacerbation. A further arterial blood gas sample was obtained, and a third OPO was recorded (study night 3 [N3]). OPO was performed using a Siemens Micro2 portable pulse oximeter (Siemens Medical Systems; Malvern, PA) with a finger probe. This device has a reported accuracy of ± 2% (within temperature range of 10 to 40°C; saturation range, 70 to 100%). A “standard” averaging time of 15 s was used. Each subject used the same pulse oximeter on all 3 nights. Instructions to subjects were to take any medication as usual, begin recording on retiring to bed with the intention of sleeping, stop recording when they awoke with no further intention of sleeping, and leave the pulse oximeter in place during brief disturbances in the night. Recordings of < 4 h in duration were considered inadequate, and were excluded and repeated the following night. All recordings were completed in the home of the subjects, and all subjects resided within the Auckland area, which is at or near sea level. The computer software package of the manufacturer was used to calculate the length and the mean nocturnal saturation (MNS) for each recording. The TB90% was also calculated; due to the software configuration, saturations of 90% were included within this measure.

Statistical Analysis

MNS and TB90% were compared for each pair of nights by plotting the difference between the 2 nights against the mean (Bland and Altman method). Mean difference and 95% limits of agreement for each comparison were calculated. Analyses were also repeated taking absolute values for the difference between the nights, in order to eliminate the direction of change. Spearman correlation coefficients were used to assess the strength of associations with nocturnal desaturation. For this comparison, mean MNS, TB90%, PO2, and PCO2 were used for each patient. Predictors of increased variability were assessed using a general linear model, except group comparisons which were made using an unpaired t test. For this purpose, variability was defined as the difference between the TB90% for the first and second nights, with the direction of change eliminated. To assess for differences in variables between all 3 nights, a repeated-measures analysis of variance was used. For all analyses, a p < 0.05 was considered statistically significant.
RESULTS

Baseline Characteristics

A total of 26 subjects participated in the study (29 subjects were approached, and 3 subjects declined to participate), of which 22 were male, 1 was a current smoker, and the other 25 were ex-smokers. Subjects had moderate-to-severe COPD with mean postbronchodilator FEV₁ of 28.6% predicted and mean reversibility of 153 mL, but relatively well preserved resting oxygenation (Table 1).

Most subjects were in stable states over the study period, and final group mean PO₂ and PCO₂ at 3 weeks were similar to baseline: 72.0 mm Hg (SD, 12.0) and 43.5 mm Hg (SD, 4.5), respectively. Despite this, 7 of 26 subjects reported exacerbation following the second recording. Two subjects returned recordings of insufficient length, both on the first night of the study.

Factors Affecting Nocturnal Desaturation

MNS and TB90% were correlated with resting PO₂ (r = 0.48 and p = 0.013, r = 0.51 and p = 0.008, respectively) and PCO₂ (r = 0.53 and p = 0.006, r = 0.48 and p = 0.014), but not FEV₁ (r = 0.06 and p = 0.76, r = 0.02 and p = 0.93).

Night-to-Night Variability of Nocturnal Desaturation

The TB90% for N3 was 35.9% for the whole study population, but this falls to 31.1% if the seven patients with exacerbations are removed; therefore, the results of N3 for these subjects are excluded from further analysis. There were no significant differences between nights for group mean recording length (N1, 408 min [SD, 62]; N2, 422 min [SD, 64]; N3, 419 min [SD, 61]; p = 0.28), mean MNS (N1, 91.3% [SD, 2.6]; N2, 91.2% [SD, 3.1]; N3, 91.6% [SD, 2.6]; p = 0.69), or mean TB90% (N1, 17.46%; N2 and N3, 9.95%; N1 and N3, 14.05%). However, much larger mean variability was seen for TB90%: N1 and N2, 17.46%; N2 and N3, 9.95%; N1 and N3, 14.05%.

There was no discernible pattern to variability in MNS (Fig 1); however, subjects exhibited less variability in TB90% if they had either very low or very high mean TB90%. Figure 3 illustrates the clinical significance of this finding. The TB90% for N1 and N2 is shown, and the horizontal line plotted through 30% (the cut-off used to define “significant nocturnal desaturation”5–7) illustrates that 9 of the 26 study patients (34.6%) changed category between significant and nonsignificant desaturation on the 2 consecutive nights.

Factors Affecting Variability of OPO

Increased variability of TB90% between N1 and N2 was not significantly related to differences in length of the recording (p = 0.23), FEV₁ (p = 0.96), the degree of reversibility of FEV₁ postbronchodilator (p = 0.17), nor whether the subjects were “good” or “poor” sleepers on the basis of Pittsburgh sleep quality index score (p = 0.52). There was no significant relationship between variability and initial resting PO₂ (p = 0.89), mean MNS (p = 0.99), or mean TB90% (p = 0.53).

Table 1—Baseline Characteristics of Study Subjects (n = 26)

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Mean (SD)</th>
<th>Range</th>
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<tbody>
<tr>
<td>Age, yr</td>
<td>69.3 (6.9)</td>
<td>59–83</td>
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<tr>
<td>Body mass index</td>
<td>23.9 (4.1)</td>
<td>16–31</td>
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<tr>
<td>FEV₁ postbronchodilator</td>
<td>0.79 (0.36)</td>
<td>0.4–2.3</td>
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<tr>
<td>FEV₁ postbronchodilator % predicted</td>
<td>28.6 (10.6)</td>
<td>17–61</td>
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<tr>
<td>Reversibility, mL</td>
<td>153 (78)</td>
<td>-40–340</td>
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<tr>
<td>Initial PO₂, mm Hg</td>
<td>71.3 (9.8)</td>
<td>49.5–96.8</td>
</tr>
<tr>
<td>Initial PCO₂, mm Hg</td>
<td>45.0 (5.5)</td>
<td>38.3–55.5</td>
</tr>
<tr>
<td>Epworth score</td>
<td>4.1 (2.6)</td>
<td>0–11</td>
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DISCUSSION

This study demonstrated considerable variability in nocturnal desaturation between nights in patients with moderate-to-severe COPD without daytime hypoxemia, when measured using home OPO. The variability was of a degree that would have influenced clinical decision making in over one third of patients. Direct assessment of nocturnal desaturation by OPO is needed in patients with COPD, because this study and previous research have shown that the degree of nocturnal desaturation such patients exhibit cannot be reliably predicted from other variables.2–5,9,10 Furthermore, home OPO is considered...
the method of choice for investigating nocturnal desaturation, since the presence of polysomnography monitoring equipment and unfamiliar surroundings may lead to underestimation of the extent of nocturnal desaturation.12

The variability of home OPO has not been studied previously to our knowledge, despite its potential clinical importance. This study demonstrated very little mean difference in mean nocturnal saturation between nights, comparable with a previous study of hospital-based OPO with polysomnography.11 However, use of the TB90% as a measure of nocturnal desaturation has become widespread.5–7 We have shown considerable variability in TB90% between nights of 10 to 17.5%. Almost 35% of our study subjects could have been classified as a “desaturator” or “nondesaturator” depending on whether the first or second recording was used. This study calls into question the validity of the current practice of using only one OPO recording to quantify nocturnal desaturation in patients with COPD. It also calls into question whether TB90% is the best measure of nocturnal desaturation, given the considerable variability demonstrated. We found that subjects with a very low or very high mean TB90% appeared to exhibit less variability in TB90% than the other subjects. This is probably explained by the “baseline” saturation of such subjects lying further away from 90%, so that they cross this threshold less often; this would also explain why a similar pattern is not seen for variability of MNS. In addition, subjects with a higher baseline saturation will have a resting PO2 outside of the “steep” part of the oxyhemoglobin dissociation curve, leading to smaller changes in nocturnal saturation for a given fall in PO2. However, the pattern of variability of TB90% demonstrated does question the wisdom of adopting a definition of significant nocturnal desaturation that incorporates a rigid cut-off in TB90% such as 30% of the night; patients with such degrees of nocturnal desaturation are particularly likely to exhibit substantial variability in TB90% between nights.

Further analysis of our study results did not reveal any other factors explaining variability of TB90%. FEV1 was not related to variability, nor was reversibility of FEV1, indicating that bronchospasm may

Figure 1. Difference in MNS plotted against mean MNS for N2 and N1 (top), N3 and N2 (middle), and N3 and N1 (bottom). Group mean difference is shown by a solid line, and 95% limits of agreement are shown by dotted lines.
not affect variability of desaturation in patients with COPD. It may have been expected that an “acclimatization effect” would be seen, with sleep disturbance due to unfamiliar equipment on N1 leading to variability between N1 and N2; however, we found no significant difference in group mean TB90% between N1 and N2, with considerable variability in both directions in individual subjects (Fig 2). It would seem that the presence of a pulse oximeter has minimal disruptive influence on estimation of nocturnal desaturation, unlike polysomnography equipment.12 We might also have expected greater variability over time than between consecutive nights, but there appears to be a similar amount of variability in both MNS and TB90% for each comparison; therefore, during assessment of clinically stable patients for oxygen therapy, it may not be necessary to carry out OPO 3 weeks apart as recommended for arterial blood gases.7

Nocturnal desaturation in COPD occurs mainly during rapid eye movement (REM) sleep,19 which tends to occur more frequently during later parts of the night. Poor sleep quality is common in patients with COPD,20,21 and thus might have been expected to disrupt REM sleep causing variability in TB90%. Formal analysis revealed no relationship between difference in recording duration and variability of TB90%, and poor sleepers did not exhibit more variability as a group than good sleepers. However, poor sleep quality leading to differing amounts of REM sleep between nights remains a likely cause of some of the variability we have demonstrated, in addition to other patient-specific rather than generic factors such as variation in the patient’s evening routines between nights. The relatively small number of patients in the study and shortcomings of our sleep questionnaire17 (which has not been previously validated for use in COPD) may explain the inability to demonstrate any formal relationship between sleep quality and variability, and further study of the mechanism behind our findings may be warranted.

The presence of sleep-disordered breathing could
have influenced our results. We excluded patients with clinical evidence of OSA from the study. It is not possible to entirely exclude OSA without undertaking polysomnography; however, we wanted the study to reflect clinical reality, whereby sleep studies are only recommended in patients with COPD in whom sleep disorder is suspected clinically. Finally, limitations of technology could also affect results, but efforts were made in our study design to minimize this: the oximeters had an accuracy of ±2% in the readings, were regularly serviced and used the “standard” averaging time of 15 s, stated by the manufacturers to be less susceptible to motion artifact. Each subject used the same oximeter on all 3 nights. Although pulse oximeters are less accurate at lower saturations, this should not affect TB90%, and subjects with low MNS did not appear to exhibit greater variability. We therefore feel that our results were not influenced by technologic limitations.

CONCLUSION

We have demonstrated that patients with COPD and nocturnal desaturation display substantial variability in the extent of nocturnal desaturation when measured at home with a pulse oximeter. Similar variability occurs both on consecutive nights and over time, and variability is greatest when desaturation is expressed as the TB90%. Differences in sleep quality, disease severity, or the length of oximetry recording did not appear to explain the degree of variability seen in this study. Thus, the current clinical practice of carrying out a single home overnight pulse oximetry recording may be inadequate for assessment of nocturnal desaturation.

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