Hour-to-Hour Variability of Oxygen Saturation in Sleep Apnea*

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Study objectives: Methods used to express the severity of oxygen desaturation during polysomnography include the average oxygen saturation (AO2), lowest oxygen saturation (LO2), and the percent of the total time with oxygen saturation level lower than 90% (T<90%). We wanted to determine which one of these methods is least variable during different hours of monitoring.

Design: Prospective, observational study.

Setting: Sleep center at a medical university.

Patients: One hundred fifty patients with apnea-hypopnea index from 5 to 130.

Measurements: AO2, LO2, and T<90% were calculated during each of the 8 h of polysomnography. Data for each hour were compared and the Cronbach alpha coefficients were calculated.

Results: There was a high degree of correlation among the three methods as well as between each method and the severity of sleep apnea. The mean±SD values for each method were as follows: AO2, 92.7±5.6; LO2, 68.5±19.3; and T<90%, 15.7±24.2. The alpha coefficients for these methods were AO2, 0.98; LO2, 0.88; and T<90%, 0.98. In all methods, the data of the first hour were significantly different from the data of the subsequent hours.

Conclusion: Both AO2 and T<90% methods show less hour to hour variability compared with LO2, and there is more variability in the first hour. Since the AO2 values >90% may not convey the severity of O2 desaturation, T<90% may be the best method of expressing oxygen saturation changes during polysomnography.

(CHEST 1998; 113:719-22)

Key words: hypoxemia; nocturnal oximetry; oxygen desaturation; sleep apnea; variability

Abbreviations: AHI=apnea-hypopnea index; AO2=average oxygen saturation; LO2=lowest oxygen saturation; REM=rapid eye movement; T<90%=percent of total recorded time spent below 90% oxygen saturation

Oxygen desaturation is common among patients with sleep apnea.1-3 Some of the methods used to express the severity of oxygen desaturation during sleep include the average oxygen saturation (AO2) level, the lowest oxygen saturation (LO2) level during the night, and the percent of the total recorded time spent below 90% oxygen saturation (T<90%).4-6 It is not known which one of these methods shows least variability during different hours of sleep. If one is to compare the oxygen saturation before or after therapy during the same night or limit the duration of the study to early or later part of the night, it would be desirable to establish which method of expressing oxygen desaturation is least variable during sleep monitoring. This study was done to determine the hour to hour variability of these three commonly used methods of monitoring oxygen saturation during polysomnography.

METHODS AND MATERIALS

The oxygen saturation data of 150 patients (with mild to severe obstructive sleep apnea) studied at the Georgia Sleep Center of the Medical College of Georgia were evaluated. These patients were undergoing polysomnography for the first time and did not receive oxygen or continuous positive airway pressure therapy during the study.

Each polysomnogram was performed in a standard fashion and consisted of an 8-h recording of an EEG, an electromyogram, an electro-oculogram, oronasal airflow, chest wall and abdominal movements, and oxygen saturation. Apneas were defined as cessation of airflow for at least 10 s. Hypopneas were defined as a decrease of 50% or greater in oronasal airflow associated with a 4% decrease in oxygen saturation. The apnea index was calculated by dividing the total number of apneas by the total number of hours of sleep, and the apnea-hypopnea index (AHI) was calculated by dividing the total number of apneas and hypopneas observed during the recording by the total time of sleep in hours. Each patient had to have at least 30 apneas and an apnea index of 5 or greater to be included in this analysis.

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Oxygen saturation was monitored continuously during the polysomnographic recording using a Biox oximeter (Model IVA; Ohmeda, Louisville, Colo) connected to a computer (IBM; Rochester, Minn). From the data, A02, LO2, and T<90% were calculated for each hour of monitoring. The correlations between the AHI and each method of expressing oxygen saturation were calculated. Further analysis was done by dividing the patients into 3 groups of 50 based on the severity of sleep apnea. Group 1 consisted of patients with AHI <20, group 2 with AHI 20 to <50, and group 3 with AHI ≥50. The data were analyzed by analysis of variance with Fisher’s modified least significant difference procedure as a post hoc test. To determine the internal consistency, the Cronbach alpha coefficient of each method was determined.

RESULTS

Complete data were available in 150 patients with obstructive sleep apnea. There were 107 male and 43 female patients with a mean age of 46.25±11.58 years and a mean weight of 111.60±28.86 kg. The mean AHI was 42.05±33.03 and ranged from 5 to 130.

The correlation coefficients between the oxygen saturation values and AHI and between the oxygen saturation values obtained by the three methods are shown in Table 1. Overall, there was a significant (p<0.05) correlation between the oxygen saturation values measured by any method and the severity of sleep apnea. Similarly, the correlations between the oxygen saturation values obtained by these methods were significant. However, when the data were analyzed according to the severity of sleep apnea, the correlations between AHI and the three methods were weakest in group 2 and strongest in group 3 patients. All correlations between AHI and the three methods in group 3 patients were significant. The correlations between A02 and T<90% were the strongest and improved progressively with the severity of the disease.

Table 1—Correlation Coefficients and Probability Values

<table>
<thead>
<tr>
<th></th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>150</td>
</tr>
<tr>
<td>AHI vs A02</td>
<td>-0.21</td>
<td>0.003</td>
<td>-0.29</td>
<td>-0.64</td>
</tr>
<tr>
<td>p</td>
<td>0.076</td>
<td>0.491</td>
<td>0.021</td>
<td>0.001</td>
</tr>
<tr>
<td>AHI vs LO2</td>
<td>-0.28</td>
<td>-0.21</td>
<td>-0.37</td>
<td>-0.67</td>
</tr>
<tr>
<td>p</td>
<td>0.024</td>
<td>0.069</td>
<td>0.004</td>
<td>0.001</td>
</tr>
<tr>
<td>AHI vs T&lt;90%</td>
<td>0.40</td>
<td>0.049</td>
<td>0.25</td>
<td>0.66</td>
</tr>
<tr>
<td>p</td>
<td>0.002</td>
<td>0.366</td>
<td>0.039</td>
<td>0.001</td>
</tr>
<tr>
<td>LO2 vs A02</td>
<td>0.093</td>
<td>0.16</td>
<td>0.68</td>
<td>0.70</td>
</tr>
<tr>
<td>p</td>
<td>0.260</td>
<td>0.122</td>
<td>0.001</td>
<td>0.001</td>
</tr>
<tr>
<td>LO2 vs T&lt;90%</td>
<td>-0.54</td>
<td>-0.27</td>
<td>-0.66</td>
<td>-0.73</td>
</tr>
<tr>
<td>p</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
</tr>
<tr>
<td>A02 vs T&lt;90%</td>
<td>-0.59</td>
<td>-0.82</td>
<td>-0.94</td>
<td>-0.94</td>
</tr>
<tr>
<td>p</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
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</table>

The mean±values of A02, LO2, and T<90% over the 8 h of polysomnography are shown in Figure 1. The mean±value for all hours for A02 was 92.7±5.6, and the hourly mean ranged from 92.20±6.21 to 93.7±4.9. The alpha coefficient was 0.98. The mean±value for all hours for LO2 was 68.5±19.3, and the hourly mean ranged between 64.6±27.4 and 72.7±25.4. The alpha coefficient was 0.88. The mean±value for all hours for T<90% was 15.7±24.2, and the hourly mean ranged from 9.7±20.3 to 18.7±29.8. The alpha coefficient was 0.98.

The highest values for A02 (93.7±4.9) and the LO2 (72.6±25.5) were seen during the first hour of the monitoring. Similarly, the lowest values for T<90% (9.79±40) were seen during the first hour of the monitoring. The oxygen saturation values during the first hour were significantly different from the remaining 7 h.

DISCUSSION

Oximetry in clinical practice has been used for more than two decades. Continuous measurement of nocturnal oxygen saturation is now routine during polysomnography, and three commonly used methods of expressing oxygen desaturation include A02, LO2, and T<90%. The results of this study suggest that the oxygen saturation values expressed by any of the three commonly used methods of monitoring continuous nocturnal oxygen saturation in sleep apnea patients have good correlations with each other, and with the severity of sleep apnea, and are fairly stable during the various hours of nocturnal polysomnography.

A greater variability in oxygen saturation values was noted during the first hour of monitoring for all three methods. The varying duration of awake time after the lights are turned off may be the main determinant of this “first hour effect.” The oxygen saturation may remain in the normal range (ie, quite different from the subsequent hours) if a patient does not go to sleep or has very little sleep during the first hour. On the other hand, the oxygen saturation is expected to decrease right from the beginning in a patient who has reduced sleep latency and, hence, early onset of apneas.

Oxygen desaturation during sleep is greater during rapid eye movement (REM) sleep compared with non-REM sleep. Oxygen desaturation is expected to be greater during the last third of the night because of the higher percentage of REM sleep during this time. In addition, it has been shown that the mean apneic duration and the sleep time spent in the apneic state increase as the night progresses.
The data in this study do not show that the last hours of sleep had more oxygen desaturation compared with the values in the earlier hours. This may be related to two factors: the variable distribution of REM sleep and the reduced rate of oxygen desaturation during sleep in sleep apnea patients. The REM latency and REM distribution are quite variable in sleep apnea patients who have extreme fragmentation of sleep. In a previous study, REM latency in sleep apnea patients was 149±98 mins with almost equal distribution of REM sleep in each one third of the night. In addition, the rate of oxygen desaturation in sleep apnea patients is significantly reduced as the night progresses. Both of these factors may decrease fluctuations in oxygen saturation in sleep apnea patients. The stability of oxygen saturation during polysomnography in sleep apnea is of concern when a study is performed at different hours of the night. A similar concern may be raised when split-night studies are performed comparing various therapeutic modalities. The data of this study indicate that the variability in oxygen saturation should not be a significant factor in such situations.

An oxygen saturation value of 90% corresponds to a PaO₂ value of 60 mm Hg. Generally, oxygen saturation values lower than 90%, particularly values lower than 88% (PaO₂, 55 mm Hg), are readily accepted as being abnormal. Oxygen saturation values above 90% may not be perceived as indicating hypoxemia. Since AO₂ values reflect both the lower oxygen saturation values secondary to apneas and hypopneas and the higher values seen during post-apneic hyperventilation and normal breathing, these usually remain >90% even in patients with severe sleep apnea. In this regard, both the LO₂ saturation and the T<90% are better indicators of hypoxemia than the AO₂ is. Since T<90% is more stable than LO₂ and is also indicative of the degree of hypoxemia, it may be the best clinical method for expressing the severity of nocturnal hypoxemia.

ACKNOWLEDGMENT: The authors thank Brenda Fedrick for her assistance in typing the manuscript.

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