Association of Apnea Hypopnoea Index with Fall in Oxygen Saturation in Patients with Obstructive Sleep Apnea

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Abstract

This proposed study aimed to find out the association of Apnea Hypopnoea Index (AHI) with Fall in Oxygen Saturation in Patients with Obstructive Sleep Apnea (OSA). OSA Syndrome (OSAS) is quite common and results from a mechanical impediment that stops airflow during sleep. Such intervals lead to temporary oxygen deficiency, which can impact the body in numerous ways. This work explored the relationship between oxygen level and the Respiratory Event Index (REI) to gain further insight into OSA. The results indicate that the Nadir Oxygen Saturation (SpO2) during sleep had a notable inverse correlation with REI ($r = -0.72$, $p < 0.001$). Positive correlation was also noted with Oxygen Desaturation Index's (ODIs) on REI ($r=0.83$ and $p < 0.001$). Regression analysis identified the ODI (Beta = 0.65, $p < 0.001$) and Nadir SpO2 during sleep (Beta = 0.13, $p < 0.001$) as significant predictors of desaturation. Conclusions: This research marks the clear relationships noted between REI and oxygen desaturation values, reinforcing concern over the ODI as an important predictor of OSA severity. Such results certainly change how OSA is approached in terms of its treatment or even advanced clinical management systems. The results clearly show the need to focus on capturing intermittent hypoxemia. New studies should be performed that are based on tracking subjects over prolonged periods to provide evidence and investigate the reasons why people differ in the way they respond to desaturation of oxygen.

Keywords: Obstructive Sleep Apnea, Respiratory Events Index, Oxygen Desaturation, Hypoxia, Oxygen Saturation, Oxygen Desaturation Index.

Introduction

Obstructive Sleep Apnea (OSA) is an alarming condition characterized by recurrent episodes of upper airway obstruction, hypoxia, sleep interruption, strain on some bodily systems (Dempsey et al., 2010). Emerging data suggests that the OSA's impact on a population is becoming more intense, estimating that close to one billion individuals suffer from OSA, with numbers expected to increase due to factors like obesity and the aging population (Morsy et al., 2019). Although common, OSA is still underdiagnosed and undertreated which poses a severe public health concern (Su et al., 2022). It is linked to an extensive list of adverse health

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outcomes such as cardiovascular illness, metabolic imbalance, changes in cognition, and diminished life quality (Calderón-Larrañaga et al., 2019). The deep understanding of patho-physiological processes and clinical aspects, including mechanisms of OSA, are essential for refining precision in diagnosing, risk assessment, and treatment strategies (Kornej et al., 2020).

The Apnea Hypopnea Index (AHI) is the most frequently mentioned span of average polysomnographic measurements used to assess the severity of OSA (Zhan et al., 2018). As a general norm, the average amounts of apneas and/or hypopneas in one hour of rest during sleep are calculated (Redline et al., 2007).

In the case of determining the existence and severity of OSA Syndrome (OSAS), the AHI is estimated to follow these criteria: mild, moderate, and severe cases with 5, 15, and 30 events/hour respectively (Malhotra et al., 2021).

However, the clinical significance of AHI has been debated, especially regarding its use as the sole measure of OSA severity. Indicatively (Pevernagie et al., 2020), the numerical value of AHI ignores the partial peripheral oxygen desaturation and its integrative effects on the body so-called systemic gross summation impact, which is often termed as the so-called ‘sick body’ and wellbeing (Crane & McGowan, 2019). This measure of AHI’s precision has induced OSA investigators to redefine clinical burden and set new standards and thresholds relying on other definers such as Oxygen Desaturation Index (ODI) and Nadir Oxygen Saturation (SpO2) (D OSA-TOM, 2008).

Reduction of SpO2 level falling below a defined threshold during sleep is considered one of the main features of OSA and has great significance in the pathophysiological perspective of the disease. Intermittent hypoxia, which describes the repetitive cycle of oxygen deficiency followed by replenishment, is known to give rise to a whole host metabolic system response inflammation oxidative stress enhanced sympathetic activity that are associated with some of the health complications linked to the disorder OSA (Rashid et al., 2021).

Relatively lower threshold level of SpO2 during sleep has a wide range of variation for everyone with OSA assigned the ‘severity index’ which consist of factors including baseline level of SpO2, recurrence rate, duration of the comorbid conditions, apneas, and hypopneas (Alvarez et al., 2010).

The proposed study aimed to determine how AHI correlates with the level of SpO2 in patients diagnosed with OSA.

Methods and Materials

Study Design and Setting

This cross-sectional research aimed to explore how the AHI score correlates with the hypoxemic levels of oxygen in patients with OSA. The Polysomnography (PSG) Stage data was analyzed using customized software in the affiliated hospital's tertiary-level sleep. Participants above the age of twenty had already completed PSG. As with all medical research ethics involving human subjects, informed consent was obtained prior to the onset of any research activities.

Study Population

The sample for this study consisted of adults with OSAS diagnosed at a sleep clinic using a physician's evaluation and PSG. Inclusion criteria were: (1) age greater than or equal to 18 years, (2) OSA diagnosed with an AHI of at least five episodes per hour, (3) receiving complete PSG with SpO2 monitoring. Patients with central sleep apnea, significant other comorbidities such as severe Chronic Obstructive Pulmonary Disease (COPD) or interstitial lung disease which significantly reduces SpO2, or those without available data were excluded from the study.

Data Collection

The extracted data came from the PSG reports of the selected eligible patients. The following parameters were documented for each participant.

- Demographic and Anthropometric Data: Age, gender, height, weight, and Body Mass Index (BMI).
- Polysomnographic Parameters: AHI, obstructive apnea index (OAI), Central Apnea Index (CAI), mixed apnea index, hypopnea index, and Respiratory Event Index (REI).
- SpO2 Metrics: Lowest oxygen desaturation during sleep, ODI, maximum desaturation percentage, and duration of minimum SpO2.
- Sleep Architecture and Positional Data: Total recording time, time in bed, total monitoring time, and time spent in different sleep positions (supine, prone, left, right, and upright).
- Heart Rate Parameters: Mean, highest, and lowest heart rates during sleep and time in bed.
- Snoring Metrics: Total snoring episodes, total duration of snoring, mean duration of snoring, and percentage of time spent snoring.

The data were systematically recorded in a structured format to ensure consistency and accuracy. The primary variables of interest were AHI and

SpO2 parameters, with a focus on the relationship between AHI and the fall in SpO2.

Polysomnography Procedure

A PSG was done overnight in a sleep laboratory with a set protocol. PSG recordings included Electroencephalogram (EEG), Electrooculography (EOG), Electromyography (EMG), Electrocardiogram (ECG), measurement of airflow, respiratory effort, and pulse oximetry. According to AASM standards, oxygen desaturation events were defined as having a decrement of 3% or more from the baseline. Oxygen desaturation events were scored based on the American Academy of Sleep Medicine (AASM) criteria and continuously measured using pulse oximetry.

Data Analysis

The main focus was to determine the relationship between the AHI and the reduction in SpO2. Polysomnographic data along with demographic and anthropometric details of the participants were summarized using descriptive statistics. Depending on the data's distribution, continuous data were reported as mean ± standard deviation or as median (interquartile range, IQR) while categorical data were given as counts and proportions.

SpO2 parameters in relation to AHI were calculated using either Pearson or Spearman correlation coefficients. These, along with positional dependencies of sleep apnea, were further explored using straightforward multivariable linear regression analysis with age, gender, and BMI added as covariates. Additional analyses were done to evaluate how other factors affected the AHI and SpO2 relations.

Ethical Considerations

The study protocol has been assessed and accepted by the ethics board of the Department of Pulmonology, Pak Emirates Military Hospital Rawalpindi 46000, Pakistan. All activities were carried out in compliance with the Declaration of Helsinki. The confidentiality of the subjects was protected through data anonymization whereby no identifiable details were used in the computation or publishing of the results. Moreover, written informed consent was obtained from each participant prior to procedure.

Software and Statistical Tools

We utilized specialized software, SPSS (25.0) or R (4.0.5), to conduct data analysis. Subsequently, the researchers set the statistical significance threshold at $p < 0.05$. Pearson correlation was used to find out the correlation between the continuous variables.

Results

The analysis shows that the AHI, which provides the same information as the REI, has a relevant value alongside oxygen desaturation in patients who suffer from OSA. Figure 1 presents a pie chart containing the gender demographics of the sample population.

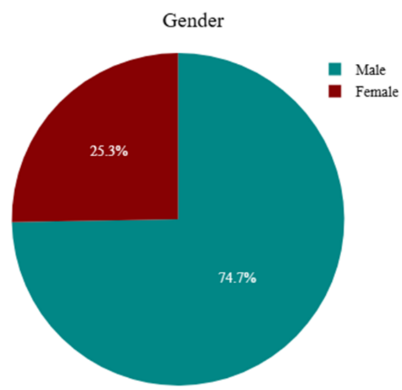

Figure 1: Gender distribution of the study population.

In terms of key variables, Table 1 contains the sample population's descriptive statistics which include: mean, standard deviation, minimum and maximum values as well. The highest attained value for duration of maximum SpO2 was 62.93 ± 359.6 seconds indicating considerable variability in SpO2 metrics within the participants.

Table 1: Descriptive statistics of the study population.

Variable	Mean± standard deviation	Minimum	Maximum
Age	50.51 ± 12.28	17	85
BMI	33.84 ± 6.9	19	34
REI	31.45 ± 27.75	0	112.4
OAI	10.08 ± 12.59	0	63.1
Lowest Desaturation	76.93 ± 12.82	33	95
Lowest SpO2 % during sleep	76.74 ± 12.86	33	94
ODI	35.12 ± 35.65	0	158.2
Duration of Min SpO2 (sec)	11.48 ± 33.21	1	53
Highest SpO2 % during sleep	97.49 ± 1.86	86	100
Duration of Max SpO2(sec)	62.93 ± 359.6	1	65

Table 2 summarizes the correlation analysis between the REI and various oxygen desaturation metrics. A strong negative correlation was observed between REI and the lowest desaturation level ($r = -0.72$, $p <$

0.001), as well as between REI and the lowest SpO2 during sleep ($r = -0.72$, $p < 0.001$), indicating that higher respiratory event frequencies are associated with greater oxygen desaturation. A strong positive correlation was found between REI and the ODI ($r = 0.83$, $p < 0.001$), reflecting the increased frequency of desaturation events with higher REI. Weak negative correlations were observed between REI and the duration of minimum SpO2 ($r = -0.19$, $p < 0.001$), as well as between REI and the duration of maximum SpO2 ($r = -0.08$, $p = 0.122$). Additionally, no significant correlation was found between REI and the highest SpO2 during sleep ($r = -0.06$, $p = 0.293$). These findings highlight the significant impact of REI on oxygen desaturation metrics, with varying degrees of association across different parameters.

Table 2: Correlation between Respiratory Events Index (REI) and oxygen desaturation metrics.

variables	r	p
REI and Lowest Desaturation	-0.72	<.001
REI and ODI	0.83	<.001
REI and Lowest SpO2 % during sleep	-0.72	<.001
REI and Duration of Min SpO2 (sec)	-0.19	<.001
REI and Highest SpO2 % during sleep	-0.06	.293
REI and Duration of Max SpO2(sec)	-0.08	.122

Table 3 presents the results of the multivariable regression analysis examining the relationship between oxygen desaturation metrics and the dependent variable. The constant term was significant ($B = -130.66$, $p = .001$), indicating a baseline effect. Among the predictors, the ODI showed a strong positive association ($B = 0.5$, $Beta = 0.65$, $p < .001$), with a narrow confidence interval (0.44 to 0.56), highlighting its significant contribution to the model. The highest SpO2 during sleep was also positively associated ($B = 1.97$, $Beta = 0.13$, $p < .001$), with a confidence interval of 1.14 to 2.79. Other variables, including the lowest desaturation level, lowest SpO2 during sleep, duration of minimum SpO2, and duration of maximum SpO2, did not show significant associations ($p > .05$). These findings emphasize the critical role of the ODI and highest SpO2 during sleep in predicting the dependent variable, while other metrics had limited predictive value.

Figure 2 illustrates a Pareto diagram of standardized effects, highlighting the relative importance of various predictors on oxygen desaturation metrics. The ODI emerges as the most significant factor, with the highest standardized effect far exceeding the critical threshold of 1.98, as indicated by the red dashed line. Other variables, such as the highest SpO2 during sleep and the lowest SpO2 during sleep, also contribute notably but to a lesser extent. Variables like the lowest desaturation (blood oxygen level), duration of minimum SpO2, and duration of maximum SpO2 have minimal standardized effects, falling below the critical threshold. This diagram underscores the dominant role of the ODI in influencing oxygen desaturation metrics, providing a clear visual representation of the relative impact of each predictor.

Table 3: Multivariable regression analysis of oxygen desaturation metrics.

Model	Unstandardized Coefficients	Standardized Coefficients				95% Confidence Interval for B	
	B	Beta	Standard Error	t	p	Lower Bound	Upper Bound
Constant	-130.66		40.3	-3.24	.001	-210.36	-50.96
Lowest Desaturation	1.09	0.5	1.22	0.89	.376	-1.34	3.51
ODI	0.5	0.65	0.03	16.68	<.001	0.44	0.56
Lowest SpO2 % during sleep	-1.7	-0.79	1.22	-1.4	.164	-4.12	0.71
Duration of Min SpO2 (sec)	-0.01	-0.01	0.02	-0.53	.597	-0.06	0.03
Highest SpO2 % during sleep	1.97	0.13	0.42	4.72	<.001	1.14	2.79
Duration of Max SpO2(sec)	-0	-0.01	0	-0.45	.654	-0.01	0

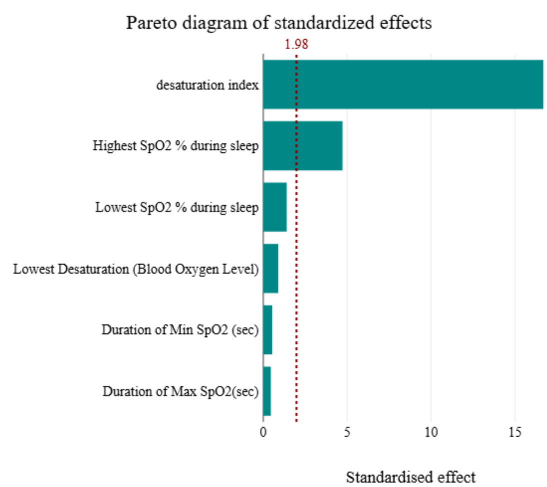

Figure 2: Pareto diagram of standardized effects on oxygen desaturation metrics.

Discussion

This work reflects the importance of the interplay between the REI and oxygen desaturation of patients suffering from OSA, highlighting key physiological and homeostatic processes which help maintain equilibrium in the body. The results illustrate noteworthy relationships between REI and SpO2 metrics such as Nadir SpO2, ODI, as well as minimum SpO2, which were observed strongly aligned with sleep. Further supporting the cumulative systematized understanding in OSA pathology; blockages result in intermixed hypoxia, oxidative turmoil as well as far-reaching impacts (Frangopoulos et al., 2020).

The correlation assessment led to the conclusion that there might be a substantial negative relationship between REI with the Nadir SpO2 ($r = -0.72$, $p < 0.001$) and lowest Nadir SpO2 during sleep ($r = -0.72$, $p < 0.001$) respectively. This confirms previous work by Bhat et al. (2018), which stated that greater apnea-hypopnea indices strongly correlated with falls in SpO2 ()." The same can be said about why REI and ODI also positively correlated, further supporting the null hypothesis as REI was expected to serve as a measure of oxygen desaturation events during heightened respiratory episodes.

In each case, the regression analysis offered deeper understanding of the predictive capability of the various metrics of oxygen desaturation. As before, the ODI was the focus because it had the highest standardized parameter estimate (Beta = 0.65, $p < 0.001$, CI = 0.44, 0.56), suggesting that it was the most important in explaining the variances oxygen desaturation. The regression analysis provided deeper understanding of the predictive ODI. Beta value shows that the importance increases in predicting OSA severity and cardiovascular risk (Slater et al., 2009). The hypothesis that higher SpO2 during sleep shows a significant positive association, suggesting that having higher SpO2 will help lessen the adverse effects of OSA. Other measurements such as rest and duration of minimum SpO2 and maximum also suggest lack of significance, but for a different reason: lack of sufficient response to hypoxemia reflects the individual response tendency most as reported earlier (Wu et al., 2015). individual variability in the response of oxygen desaturation has consequences for clinical presentation and outcomes of these patients (Adingupu et al., 2015).

The scatterplot matrix demonstrated the relationships between respiratory and SpO2 measurements and showed the impact that respiratory phenomena have on oxygen balance.

The correlation of REI with the lowest SpO2 showed strong negative correlations, which is in line with the pathophysiological aspects of OSA. This is also consistent with Huang et al. (2023) who showed that the severity of OSA correlates with the amount of desaturation of oxygen and its impairing effects like hypertension and cardiovascular morbidity. On the other hand, the correlation of REI with the duration of minimum SpO2 and maximum SpO2 showed weak or no correlation at all. This indicates that these parameters are not strong indicators of the severity of OSA (Huang et al., 2023).

This study adds to previously published data by providing detailed examination of the relationships between REI and oxygen desaturation metrics using both correlation and regression analysis to measure the effect of various predictors. This is in-synch with existing literature which emphasizes the need to manage the severity of OSA in relation to the impact it has on oxygen homeostasis and relevant health concerns. But this study also pointed other areas needing more attention, such as the individual differences in the responses of oxygen desaturation, or the possibility of being protected by high levels of SpO2 while sleeping (Quarrie, 2015).

The results from this research offer important practical adaptations. The relationship noted between REI and oxygen desaturation metrics strongly accentuates the asphyxial episodes of OSA have to be assessed rigorously especially with respect to the respiratory system and the blood oxygen level endpoints. Cardio-Respiratory Arousal-Destabilization Index (CADOI) also referred to as the ODI, one of the more important criteria pertaining OSA and its systemic sequelae is undervalued as a risk-stratification helping concern. This index is highly active in aiding classification for therapeutic measures such as Continuous Positive Airway Pressure (CPAP) which is reputed for enhancing SpO2 levels and diminishing cardiovascular morbidity among OSA afflicted patients (BaHammam & Hunasikatti, 2023). Other than that, the findings further enhance the understanding of optimal SpO2 levels during slumber as having the potentiality to protect against negative outcomes of OSA.

Nonetheless, there are several unexplored factors in this study that need attention. The results might not be applicable to patients with varying demographic or clinical features due to the lack of longitudinal studies. Apart from those, no other potential confounding factors were adapted which were more concerning such as coexisting diseases and therapeutic substances known to influence oxygen desaturation metrics. Adjusting and bridging these gaps can lead to lucrative conclusions describing weak bonds between rest asphyxia episodes and SpO2.

Highlighting the importance of this work, it incorporates data concerning the physiologic effects rest apnea syndrome has on patients while monitoring Rest oxygen data saturation revealing Oxygen rest saturation as the main unsolved target during resynthesis.

Correct assessment and management of OSA is important and these findings highlight the need for specific strategies to correct the pathophysiologic mechanisms of the disorder to achieve better results. Additional studies should look into factors that explain individual differences in desaturation response as well as the impact of keeping SpO2 at an optimal level during sleep over prolonged periods of time.

Conclusion

This research underlines the importance of the ODI and the Nadir SpO2 in anticipating the severity of OSA in relation to the major correlations between REI and oxygen desaturation in the patients with OSA. The data obtained from the analysis demonstrate the reduction of respiratory events in REI to oxygen homeostasis and its key values, such as lowest SpO2 and ODI. REI exhibits a strong relationship with these key metrics. As to the answers provided by the research, these pointers are vital for understanding OSA and its effects on the body systems alongside the critical need for proper diagnosis tools so that the problems associated with hypoxia are avoided.

Limitations

This study has a few limitations that are worth discussing. Firstly, the simultaneous measurements of REI and oxygen desaturation levels rule out causal linkages due to the lack of longitudinal data. Secondly, the sample population's characteristics has narrow representational scope which restricts the extent of the findings. Thirdly, other existing variables like preexisting medical conditions, medications taken, and day-to-day life were not incorporated into the examination analysis which may alter the results. Fourth, the OSA metrics does not measure OSA severity over time and gives a static snapshot that may not accurately represent dynamic OSA characteristics.

Future Recommendations

The longitudinal designs and the determination of the OSA effects on oxygen homeostasis and systemic health over time should be added in the following pieces of research to solve the drawbacks discussed in previous studies. Multivariable analyses, alongside broader population samples, will enhance generalizability as well as account for possible confounding factors. The gaps in the OSA heterogeneity will be studied while looking into the individual differences of oxygen desaturation responses. The overall effectiveness and the systemic risk reduction will be assessed to determine if optimal patient outcomes are achieved through CPAP therapy.

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