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New Indices from Polysomnographic Measures for the Severity of Obstructive Sleep Apnea Syndrome –A Different Look at Obstructive Sleep Apnea Syndrome

Obstrüktif Uyku Apne Sendromu Şiddeti için Yeni Polisomnografik Veri İndeksleri –Obstrüktif Uyku Apne Sendromuna Farklı Bir Bakış

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ABSTRACT

Introduction: Obstructive sleep apnea syndrome (OSAS) is characterized by recurrent abnormal respiratory events during sleep and causes oxidative stress which is reported as a major pathogenic mechanism for the development of various cardiovascular disorders. For the diagnosis and management of treatment, disease-related symptoms and the Apnea-Hypopnea Index (AHI) measured from polysomnographic (PSG) recordings are taken together. However, AHI do not sufficiently represent the total hypoxic load, and other indices related to apnea frequency, apnea duration, and desaturation degree should be investigated.

Methods: In this study, 317 polysomnographic recordings were retrospectively evaluated. Apart from the conventional AHI, apnea and/or hypopnea duration percentage (AHDP) and desaturation area (DesatArea) were calculated using PSG data.

Results: According to the AHI, 21.8%, 32.8% and 45.4% of cases were grouped as mild, moderate and severe OSAS, respectively. When AHDP was taken into account, 10.4%, 22.1% and 67.5% of the cases were regrouped as mild, moderate or severe OSAS, respectively. When the DesatArea calculation was used, the grouping of cases as mild, moderate or severe OSAS changed in value to 10.7%, 21.1% and 68.1%, respectively. The total group change was found to be 58.4% for both the AHDP and DesatArea formulation. With the AHDP formulation, regrouping was made in 52.2% of the mild OSAS cases and 62.5% of the moderate OSAS cases; by using the DesatArea calculation, 50.7% of mild OSAS cases and 63% of moderate OSAS cases were regrouped.

Conclusion: Our results show that when another parameters related to abnormal respiratory events are used, the same patients within the same group of disease severity are heterogeneously separated according to severity of hypoxia. It is suggested that grouping the patients based on AHI is insufficient and that using other polysomnographic measurements along with AHI should be considered to represent the severity of the disease.

Key words: desaturation, apnea duration, obstructive sleep apnea, severity

ÖZ

Amaç: Obstrüktif uyku apne sendromu (OUAS) uykuda tekrarlayan anormal solunum olayları ile karakterize olup, çeşitli kardiyovasküler hastalıkların altında yattığı bildirilen majör patojenik mekanizmayı teşkil eden oksidatif strese neden olur. Tanıda ve tedavi yaklaşımın belirlenmesinde hastalıkla ilişkili semptomlar ve polisomnografi (PSG) incelemesinde elde edilen apne/hipopne indeksi (AHİ) değerleri dikkate alınmaktadır. Ancak, AHİ değeri gece içerisinde ortaya çıkmış olan toplam hipoksi yükünü tam olarak temsil etmemektedir. Bu nedenle apne sayısı, süresi ve desaturasyon derecesi ilişkili diğer indekslerin araştırılması gerekmektedir.

Yöntem: Çalışmamızda retrospektif olarak 317 PSG verisi değerlendirilmiş; konvansiyonel AHİ hesaplaması yanı sıra, apne hipopnede geçen toplam uyku yüzdesi (AHSY) ve desaturasyon alanı (DesatAlan) değerleri hesaplanarak OUAS gruplaması yeniden yapılmıştır. Sonuçlar: AHİ değerine göre hafif, orta, ağır OUAS gruplarının dağılımı sırasıyla %21,8, %32,8, %45,4 iken; AHSY verilerine göre olgular yeniden gruplandırıldığında dağılım %10,4, %22,1, %67,5 olarak değişkenlik göstermiştir. DesatAlan verilerine göre gruplandırma yapıldığında hafif, orta ve ağır OUAS oranları sırasıyla %10,7, %21,1, %68,1 olarak bulunmuştur. AHSY ve DesatAlan verilerine göre gruplandırmadaki değişim oranı her iki parametreye göre de %58,4 olup, birbirlerine göre farklılık ortaya koymadıkları izlenmiştir. AHSY ve DesatAlan'a göre hafif olguların sırasıyla %52,2 ve %50,7'sinde, orta OUAS olgularının sırasıyla %62,5 ve %63'ünde gruplandırma değişikliği ortaya çıkmıştır. Hafif olgulardaki grup değişimi çoğunlukla orta olmak üzere orta ve ağır OSAS yönünde olmuş, orta OUAS olgularında grup değişimi gösterenler ağır OSAS olarak yeniden gruplandırılmıştır.

Sonuç: Sonuç olarak; farklı parametreler kullanıldığında aynı hastalık şiddeti alt kategorisi içerisinde değerlendirilen olguların hipoksi şiddeti açısından farklılık gösterdikleri görülmüştür. Bu nedenle, AHİ değeri temelinde yapılan gruplamanın hastalık şiddetini yansıtmada yetersiz olduğunu, diğer polisomnografik verilerin değerlendirmeye katılması gerektiği düşünülmektedir.

Anahtar Kelimeler: Desatürasyon, apne süresi, obstrüktif uyku apne, şiddet

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INTRODUCTION

Obstructive sleep apnea syndrome (OSAS) is the most commonly observed sleep-related breathing disorder in adults. It is characterized by repetitive apnea and/or hypopnea episodes due to temporary obstructions of the upper airway. Abnormal breathing events occur as apnea and/or hypopnea are accompanied by decreased oxygen saturation of different levels. This repetitive hypoxia-reoxygenation along with any abnormal breathing event cause oxidative stress, which is one of the main mechanisms in the pathophysiology of OSAS-associated cardiovascular morbidity (1, 2).

In clinical practice, apnea-hypopnea index (AHI) is used to validate the diagnosis of OSAS and to determine its severity. AHI reflects the frequency of abnormal breathing events per hour of sleep without taking into consideration the duration of apnea or the level of desaturation related with it. However, it is well-known that oxidative stress is associated with the duration and severity of hypoxia (3–5). Recent clinical studies that focus on the severity of obstruction in connection to the duration of apnea and desaturation suggest that conventional AHI classification does not provide adequate perspective and that new scales including the duration of apnea and desaturation should be developed in order to have a wider point of view (6–9).

In this study, we aimed to demonstrate the changes that are observed in classifications based on the conventional AHI when new indices that include the duration of apnea and desaturation are introduced.

METHODS

The subjects included in our study were determined by retrospectively reviewing the records of patients who were treated by the Sleep Disorders Unit of the Department of Neurology in the Dokuz Eylül University Medical Faculty between January 2007 and May 2013 with the complaint of snoring and pauses in breathing during sleep, who were considered to have OSAS in the pre-evaluation, and for whom a polysomnography (PSG) was performed. All participants were informed about the aim of the study and each participant read and signed the informed consent form. The study was approved by the Ethics Committee of Dokuz Eylül University Hospital.

Only adult patients (≥18 years of age) were included in the study. Subjects with chronic obstructive pulmonary disease, asthma, severe cardiac failure, neuromuscular disorders or alcohol/substance abuse were excluded. Patients with narcolepsy or idiopathic hypersomnia were also excluded.

Polysomnography recordings were performed using Embla®S4000 and Embla®N7000 (Natus Medical Inc., California, USA) devices. Video-PSG included six EEG channels (according to International 10-20 system F3, F4, C3, C4, O1 and O2) and other channels that record parameters required for clinical polysomnographic evaluation: right and left electrooculography, submental and bilateral tibialis anterior surface electromyography, electrocardiography, oronasal air flow (with thermistor and nasal cannula), recording of breathing movements of thorax and abdomen with plethysmograph, finger pulse oximeter for measuring oxygen saturation, body position recordings, video recordings with an infrared light camera and a laryngeal microphone for snoring sound recordings.

Sleep staging and respiratory event scoring of the PSG recordings were performed according to the AASM 2012 guidelines. Subjects with a total sleep duration of a minimum of 3 hours and AHI≥5 were included in the study. The upper limit of AHI was considered <60. OSAS was staged depending on the AHI value, and the patients were classified into three groups: mild (5≤AHI<15), moderate (15≤AHI<30) and severe (30≤AHI<60). AHI, mean apnea duration, mean oxygen desaturation and total sleep duration parameters, which are obtained from the PSG recordings, constituted the data used in the study. The age, sex and body mass index (BMI) information of all subjects were also recorded.

Along with the conventional AHI that is widely used in the diagnosis and staging of OSAS, modified AHI values, which comprise the mean apnea duration and mean desaturation, together with the number of apneas and are considered to better reflect the severity of disease in recent studies, were formulized. The two equations derived are as follows:

Apnea-hypopnea duration percentage=(AHI x Mean apnea hypopnea duration [sec])/36

Desaturation area=AHI x Mean apnea duration (sec) x Mean desaturation (%)

When calculating the apnea-hypopnea duration percentage (AHDP), the number of abnormal breathing events in the form of apnea-hypopneas per hour is multiplied by the mean apnea hypopnea duration (in seconds) and the total duration of abnormal breathing events per hour is obtained on the basis of seconds. The total duration of abnormal breathing events per hour represented as a percentage is divided by 36 to determine the final value. This value, expressed as AHDP, is the percentage of an hour that is passed with abnormal breathing events.

When calculating the desaturation area (DesatArea), the number of apnea-hypopneas per hour, mean apnea duration (seconds) and mean desaturation percentage (%) are multiplied. This value is considered the profundity of total abnormal breathing events per hour.

Subjects were re-evaluated according to the AHDP and DesatArea calculations. Then the rate of change from the conventional AHI classification was computed.

Statistical analysis

The statistical analysis of the study was performed using SPSS 17.0. The normality of the variables was assessed with visual (histogram) and analytic methods (Kolmogorov-Smirnov and Shapiro-Wilk tests). Descriptive analyses are given as a mean and standard deviation for variables with normal distribution. A Student's t test was used when comparing two independent groups with normal distribution, whereas a one-way ANOVA was preferred for the comparison of more than two groups. Double post-hoc comparisons were performed when a significant difference was found between groups. $P<0.05$ was considered statistically significant.

RESULTS

A total of 317 subjects were included in the study. Of these, 25.2% (n=80) were female and 74.8% (n=237) were male. Age, BMI, total sleep duration, mean apnea duration and mean oxygen desaturation percentages of all subjects are shown in Table 1.

The AHI values of the subjects included in the studies varied between a minimum of 5 and a maximum of 59.3. When the subjects were grouped according to the AHI, 21.8% of the patients (n=69) had mild, 32.8% (n=104) had moderate and 45.4% (n=144) had severe OSAS. There was no statistically significant difference between age, total sleep duration and mean apnea duration among the mild, moderate and severe OSAS groups. However, BMI and mean oxygen desaturation were significantly different between the groups (p=0.008 and p≤0.0001, respectively) (Table 2). Post-hoc subgroup analyses revealed BMI to be significantly different between mild and severe OSAS groups in favor of the severe group

Table 1. Demographic and polysomnographic data of all patients

	Minimum	Maximum	Mean (SD)
Age (year)	20	85	52.2 (±11.7)
BMI (kg/m^2)	19.7	49.5	29.7 (±4.9)
Total sleep time (minute)	192	548	406.1 (±58.4)
AHI	5	59.3	29.3 (±15.1)
Apnea duration (second)	14.9	59.1	26.5 (±6.7)
O_2 desaturation (%)	3	21.4	6.5 (±2.5)

AHI, apnea hypopnea index; BMI, body mass index; SD, standard deviation.

(p=0.006). In terms of oxygen desaturation, the severe OSAS group was significantly different from mild and moderate OSAS groups (p≤0.0001) (Table 2).

1. OSAS groups according to apnea-hypopnea duration percentage (AHDP)

The AHDP values of the subjects were obtained using the formula stated above in order to determine the percentage of sleep passed with apnea and/or hypopnea. The AHDP values of the OSAS groups classified according to conventional AHI are shown in Table 3.

The AHDP values of the mild OSAS group varied between a minimum of 2.80 and a maximum of 17.53. This range includes the minimum AHDP of the moderate OSAS group, which is 6.97, and the minimum AHDP of the severe OSAS group, which is 13.43. The AHDP values of the moderate OSAS group varied between a minimum of 6.97 and a maximum of 31.80. Subjects with AHDP≥13.43 overlapped with the ADHPs of severe OSAS patients.

Regrouping was performed by including the subjects with ADHP in the range that overlaps between groups to the higher severity groups.

a. 101 (58.4%) of the 173 subjects in the mild and moderate OSAS groups changed groups.

b. 52.2% of the subjects (n=36) in mild OSAS group were reclassified as moderate or severe OSAS, whereas 47.8% (n=33) had no change. Among the 36 subjects that were reclassified, 31 (86.11%) were included in the moderate and five subjects were included in the severe OSAS group.

c. 62.5% (n=65) of the patients in the moderate OSAS group were reclassified as severe OSAS, whereas 37.5% (n=39) had no change.

Subjects that had a group change (n=101) or no group change (n=72) according to AHDP had no statistically significant difference in terms of age (p=0.109), BMI (p=0.09), AHI (p=0.25) and total sleep duration (p=0.58). However, mean oxygen desaturation was significantly different between the two groups (p=0.000) (Table 4).

Patients in the mild OSAS group that had a group change (n=36) or no group change (n=33) according to AHDP had no statistically significant difference in terms of age (p=0.60), BMI (p=0.94) and AHI (p=0.057). However, the mean oxygen desaturation was significantly different between the two groups (p=0.014).

Patients in the moderate OSAS group that had a group change (n=65) or no group change (n=39) according to AHDP had no statistically significant difference in terms of age (p=0.06) and AHI (p=0.30). However, BMI (p=0.03) and mean oxygen desaturation (p=0.017) were significantly different between the two groups.

Table 2. Demographic and polysomnographic data in OSAS severity groups

		Mild (n: 69)	Moderate (n: 104)	Severe (n: 144)	p
Age (year)	Mean	49.52	52.7	53.14	0.093
	Minimum	20	30	27	
	Maximum	77	85	77	
	SD	12.11	12.66	10.62	
BMI (kg/m^2)	Mean	28.14	29.88	30.34	0.008
	Minimum	19.9	22.6	19.7	
	Maximum	43.3	49.5	46.1	
	SD	4.48	5.04	4.87	
AHI	Mean	10.32	22.34	43.46	
	Minimum	5	15	30	
	Maximum	14.8	29.7	59.3	
Apnea duration (second)	Mean	26.28	25.6	27.32	0.128
	Minimum	16.5	14.9	15.4	
	Maximum	45.4	48.1	59.1	
	SD	6.22	5.6	7.5	
Desaturation percentage (%)	Mean	5.15	5.77	7.58	≤0001
	Minimum	3	3.7	4	
	Maximum	11.7	10.1	21.4	
	SD	1.44	1.39	2.96	

AHI, Apne hypopnea index; BMI, Body mass index; SD, Standard deviation.

Table 3. AHDP and DesatArea values between conventional OSAS severity groups

		Mild (n: 69)	Moderate (n: 104)	Severe (n: 144)
AHDP	Mean (SD)	7.64 (±3.12)	15.95 (±4.84)	33.57 (±13.35)
	Minimum	2.8	6.97	13.43
	Maximum	17.53	31.8	80.71
DesatArea	Mean (SD)	1463.95 (±906.41)	3395.71 (±1589.80)	10168.06 (±8824.01)
	Minimum	432.8	1254.6	2611.22
	Maximum	5453.53	8814.81	59701.72

AHDP, apnea hypopnea duration percentage; DesatArea, desaturation area; SD, standard deviation.

2. OSAS groups according to desaturation area

DesatArea, which reflects the "total desaturation area per hour," is calculated using the formula stated above in order to reveal the profundity of hypoxia. The desaturation area values of the OSAS groups classified according to conventional AHI are shown in Table 3.

The desaturation area values of the mild OSAS group varied between a minimum of 432.80 and a maximum of 5453.53. Subjects with a desaturation area ≥1254.60 overlapped with the moderate and severe OSAS groups. Likewise, patients in the moderate OSAS groups with desaturation area ≥2611.22 overlapped with the severe OSAS group.

Regrouping was performed by including the subjects with DesatArea in the range that overlaps between groups to the higher severity groups.

a. 101 (58.4) of the 173 subjects in the mild and moderate OSAS groups changed groups.

b. Among the subjects in the mild OSAS group, 50.7% (n=35) were reclassified as moderate or severe OSAS, whereas 49.3% (n=34) had no change. Among the 35 subjects that were reclassified, 29 (82.85%) were included in the moderate and six subjects (17.1%) were included in the severe OSAS group.

c. Among the patients in the moderate OSAS group, 63.46% (n=66) were reclassified as severe OSAS, whereas 36.54% (n=398) had no change.

Subjects that had a group change (n=101) or no group change (n=72) according to desaturation had no statistically significant difference in terms of age (p=0.16), BMI (p=0.24), AHI (p=0.53) and total sleep duration (p=0.23). However, mean apnea duration was significantly different between the two groups (p=0.006) (Table 5).

Table 4. Properties of patients that demonstrate group change according to AHDP values

	with group change (n: 101) mean ± SD	without group change (n: 72) mean ± SD	P
Age (year)	52.04 (±10.98)	51.00 (±13.53)	0.109
BMI (kg/m²)	29.76 (±5.49)	28.79 (±4.40)	0.096
TST (minute)	399.83 (±59.60)	405.51 (±59.27)	0.58
Mean Apnea Duration (second)	22.16 (±3.64)	28.53 (±5.70)	**0.001**
Mean Desaturation (%)	5.20 (±1.047)	5.77 (±1.63)	**0**
AHI	14.11 (±6.09)	20.00 (±6.59)	0.259

AHI, apnea-hipoapnea index; BMI, body mass index; SD, standard deviation; TST, total sleep time.

Table 5. Properties of patients that demonstrate group change according to desaturation values

	With group change (n: 101) mean ± SD	Without group change (n: 72) mean ± SD	p
Age (year)	51.41 (±13.49)	51.47 (±11.07)	0.163
BMI (kg/m²)	29.01 (±4.58)	29.45 (±5.32)	0.244
TST (minute)	402.07 (±57.05)	404.65 (±62.69)	0.234
Mean apnea duration (second)	28.28 (±5.74)	22.50 (±4.09)	**0.006**
Mean desaturation mean (%)	6.09 (±1.53)	4.75 (±0.81)	**0**
AHI	19.84 (±6.54)	14.35 (±6.38)	0.538

AHI, apnea-hipoapnea index; BMI, body mass index; SD, standard deviation; TST, total sleep time.

Patients in the mild OSAS group that had a group change (n=35) or no group change (n=34) according to DesatArea had no statistically significant difference in terms of age (p=0.63) BMI (p=0.47) and mean apnea duration (p=0.09). However, the AHI was significantly different between the two groups (p=0.02).

Patients in the moderate OSAS group that had a group change (n=66) or no group change (n=389) according to DesatArea had no statistically significant difference in terms of BMI (p=0.20) and AHI (p=0.47). However, age (p=0.03) and mean apnea duration (p=0.010) were significantly different between the two groups.

The rate of change in mild or moderate OSAS when the conventional AHI classification was revised with AHDP was not significantly different from the rate of change in mild or moderate OSAS when the conventional AHI classification was revised with DesatArea (Table 6).

Table 6. OSAS severity groups according to AHI, AHSY and DesatArea

	Mild (%)	Moderate (%)	Severe (%)
AHI	69 (21.8)	104 (32.8)	144 (45.4)
AHDP	33 (10.4)	70 (22.1)	214 (67.5)
DesatArea	34 (10.7)	67 (21.1)	216 (68.1)

AHDP, apnea hypopnea duration percentage; AHI, apnea hypopnea index; DesatArea, desaturation area.

DISCUSSION

AASM and ICSD guidelines, which are widely used internationally for the diagnostic and therapeutic approach to OSAS, are continuously revised with the increasing data related to its pathogenesis and long-term morbidity. The apnea diagnosis criteria recommended in the 2012 AASM guidelines do not require desaturation accompanying an apnea event. In the same guidelines, a minimum of 3% oxygen desaturation is considered adequate for an abnormal breathing event to be considered hypopnea and oxygen desaturation is not even required when the abnormal breathing event is associated with arousal. The guide establishes 10 seconds as the minimum time required for an abnormal breathing event to be considered apnea or hypopnea. Polysomnographic diagnosis of the syndrome is made by measuring the frequency of abnormal breathing events, namely AHI, which are determined by the defined time and desaturation criteria, per hour (i. e., Apnea-Hypopnea Index). The severity of disease is also determined by this frequency. Thus, the profundity of desaturation and length of apnea duration do not determine the severity of the syndrome, and different values of desaturation and apnea duration can be included in the same category.

OSAS is the most frequent type of sleep-related breathing disorders and associated with wide range of disorders such as cardiovascular diseases, stroke, neurocognitive disorders (10–12). One of the major mechanisms underlying these disorders is the oxidative stress caused by repetitive deoxygenation-reoxygenation episodes due to OSAS. Different studies have shown that the time spent in hypoxia and the severity of hypoxia are the determinants of oxidative stress along with the frequency of hypoxia. (13–17).

Therefore, classifying OSAS based on the AHI indicates that only the number of repeated abnormal breathing events is considered, whereas time spent in hypoxia and the severity of hypoxia parallel to the profundity of desaturation are ignored. In our study, the percentage of sleep spent in apnea/hypopnea was a maximum of 17% in the mild group, whereas it reached up to 80% in the severe group. When the patients were regrouped considering the duration of apnea and profundity of desaturation and the new groups were compared with the former, a significant increase in the number of patients in the moderate and severe group was observed, whereas the number of patients included in the mild group shrank. According to the total apnea/hypopnea percentage calculation that covers both the mean apnea duration and the AHI (AHDP), 52.2% of the mild OSAS cases (mostly being moderate OSAS), 62.5% of the moderate and 58.4% of all mild and moderate OSAS cases changed categorization. Similarly, according to the desaturation calculation that covers the mean apnea duration and the AHI (AHDP) along with mean desaturation percentage, 50.7% of the mild OSAS cases (mostly being moderate OSAS), 63.46% of the moderate and 58.4% of all mild and moderate OSAS cases changed categorization. There was no significant difference between the cases that changed or did not change categories in terms of age and BMI.

Recent studies point out that AHI only reflects one side of OSAS and that different parameters need to be taken into consideration in order to determine the severity of obstructive events. Thinking that the conventional AHI neither reflects the duration of apnea events nor takes the profundity of desaturation into account, Otero et al. (2012) investigated the significance of other indices in differentiating healthy controls and patients with OSAS. The researchers calculated the involved sleep percentage by considering the combined duration of apnea, hypopnea and desaturation and showed that this value to be superior to AHI in differentiating healthy controls from patients with OSAS.

Muraja-Murro et al. (6) calculated the AHI by evaluating the severity of obstructive apnea/hypopnea on the basis of desaturation and apnea duration and showed that all-cause mortality and cardiovascular mortality risk rates were higher in the groups classified as moderate and severe OSA. Patients who experience more severe obstructive events are exposed to more serious health problem. In order to identify the patients in this group, the researchers point out that it would be more accurate to consider OSAS from this point of view.

Assuming that AHI is not an adequate criterion in determining the severity of disease, Kulkas et al. (8) retrospectively analyzed the PSG data of 19 subjects (4 cases each in normal, mild and moderate OSAS groups; 7 cases in the severe OSAS group) in their study. In addition to the AHI and oxygen desaturation index, the researchers re-evaluated the PSG data with the new indices about the time and severity of disease that they developed for the study. When approached with desaturation and the severity of obstruction parameter, different severity values came up within the group and intersections between groups were observed. AHI was found to be moderately correlated with desaturation and the severity of obstruction. It was reported that AHI is not a sufficient criterion for determining the severity of disease and that the new recommended parameters provide additional data in this context. These differences may reflect the level of impact on physiological compensation mechanisms. Another study (9) conducted in the same research center retrospectively evaluated the association of parameters, which were defined in the previous study and reflect the severity of disease, with mortality. Included in the study were 160 male patients, with 40 patients each in normal, mild, moderate and severe OSAS groups. Each AHI group was then divided into two subgroups having the lowest and highest novel parameter values. The results of this study demonstrate that the severity of obstruction varies greatly within the OSAS categories and that the severity of obstruction is only moderately correlated with AHI. Total mortality was found to be 16.9%, with a significant difference in mortality between patients with higher and lower novel parameter values. The researchers claim that the obstruction severity parameter, which is different from AHI by considering abnormal breathing event durations and related desaturation, more elaborately reflects the health outcomes of disease.

In their study, Muraja-Murro et al. (18) compared the PSG parameters, total mortality and cardiovascular morbidity rates of 804 subjects in a mean 198 months of follow-up. All-cause mortality and cardiovascular morbidity-related mortality were higher in moderate and severe OSA groups defined with the modified AHI than in groups defined with the conventional AHI. The researchers emphasize that utilizing modified AHI along with conventional AHI provides additional information about OSAS and contributes to better identify patient groups with higher mortality and cardiovascular morbidity.

Recent studies, which are mentioned above, demonstrate that the AHI criteria that is used in the diagnosis and staging of disease does not reflect all dimensions of OSAS. Although the clinical equivalent is lacking, our study reveals that when re-assessed with novel parameters, subjects that are treated in mild and moderate groups are quite heterogeneous.

The underlying mechanisms of different durations of apnea and different desaturation values are still unclear. It is assumed that as the disease gets more chronic, the duration of apnea and desaturation change. When the prognosis of patients who receive a diagnosis of OSAS, but are not treated due to compliance issues or refusal of treatment is evaluated, oxygen desaturation level or the duration of apnea is shown to increase with or without a rise in AHI and independent of BMI.

The limitations of our study are:

1. When the percentage of sleep affected by apnea/hypopnea is calculated, we used the value acquired by multiplying the mean apnea duration with the AHI. However, in order to create a more accurate representation, abnormal breathing events that are observed over a whole night's sleep should be added one by one, in a fashion that would represent spontaneous changes in duration or changes related to sleep stage or position and be divided by sleep duration, rather than using mean apnea duration and Apnea-Hypopnea Index per hour.
2. The method used to calculate the profundity of desaturation does not completely reflect the actual value. Calculating the area under the curve that represents the start, deepening and recovering of desaturation in each abnormal breathing event would be the most accurate and realistic approach. The profile of this curve was overlooked in the method that we used. Spontaneous, sleep stage or position-related changes in desaturation and curve variability were also ignored, and mean desaturation was considered instead.
3. The laboratory or clinical equivalents of the change that resulted from re-evaluating the severity of disease with novel indicators were not investigated in our study.

Further studies are required to fully investigate the differences in grouping when the categories are re-evaluated with novel parameters assumed to reflect disease severity with clinical and laboratory comparative assessments. Further research is also needed to develop a more realistic index defining methods related to the different aspects of the disease. Also, the cut-off values for the novel parameters should be determined for the distinction of mild, moderate and severe forms of disease.

In conclusion, the association of desaturation with the morbidity and mortality posed by the disease is confirmed in animal models and human studies. Although desaturation is demonstrated to be one of the main mechanisms responsible for the cardiovascular, cerebrovascular and neurocognitive disorders in OSAS, the AHI parameter is the only PSG data used for disease staging. The duration of apnea and desaturation level are not taken into account. In fact, the total duration of time spent in apnea and the profundity of desaturation that occurs in each apnea build the hypoxic burden that the individual is exposed to during the night. When the disease is addressed with conventional evaluation and calculation methods, long/short apnea durations and/or profound/mild desaturations are not reflected in the AHI and their clinical equivalent is disregarded. It is reasoned that AHI has its limitations and that data acquired using a modified AHI including desaturation, duration of apnea and other similar novel parameters would provide a broader perspective to our understanding of the diagnosis, staging and effects of the disease.

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