Turkish Archives of Otorhinolaryngology
Türk Otorinolarengoloji Arşivi

Turk Arch Otorhinolaryngol 2018; 56(3): 149-54

Predicting Severe Sleep Apnea in Patients with Complaints: Pulse Oximetry and Body Mass Index

Original Investigation

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Abstract

Objective: An adequate evaluation combined with an easily accessible test would be a useful way to direct the appropriate patients to sleep centers in circumstances with a limited opportunity for polysomnography (PSG). For this reason, it is necessary to use a screening method prior to PSG evaluation. The aim of the present study was to investigate whether the use of body mass index (BMI) and pulse oximetry is sufficient to predict the severity of obstructive sleep apnea syndrome (OSAS) without PSG.

Methods: A total of 956 patients who were admitted to a tertiary referral center with complaints of witnessed apnea, excessive daytime sleepiness, and previously performed PSG were included in the study. Data of PSG (included pulse oximetry) and BMI were investigated for the determination of cut-off points for parameters in the patients.

Results: Based on the presence of severe OSAS, the cut-off points were ≥31.7 kg/m^2 for BMI, <81% for minimum oxygen saturation (Min O_2), and ≥14.1 min for sleep time with oxygen saturation <90% (ST_{90}). Severe OSAS risk was found to be higher in patients with BMI ≥31.7 kg/m^2, ST_{90} ≥14.1 min, and Min O_2 ≤81% than in those without (OR: 37.173; 95% CI: 22.465–61.510, p=0.001). Specificity and accuracy were 94.85% and 72.49%, respectively, when all three cut-off scores were provided.

Conclusion: The appropriate cut-off values obtained from combining BMI and pulse oximetry data can provide accurate results for predicting the severity of OSAS.

Keywords: Sleep apnea, diagnosis, polysomnography, body mass index, pulse oximetry

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Cite this article as: *Kum RO, Sazak Kundi FC, Baklacı D, Yurtsever Kum N, Güler İ, Yılmaz YF, et al. Predicting Severe Sleep Apnea in Patients with Complaints: Pulse Oximetry and Body Mass Index. Turk Arch Otorhinolaryngol 2018; 56(3): 149-54.*

This study was presented at the 7th Sleep Disorders Congress, April 27- May 1, 2018, Antalya, Turkey.

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Received Date: 08.10.2017
Accepted Date: 04.05.2018

DOI: 10.5152/tao.2018.2928

Introduction

Obstructive sleep apnea syndrome (OSAS) is a disease characterized by complete or partial obstruction of airflow in the upper airway during sleep (1). Many diseases including cardiovascular diseases, hypertension, stroke, and decreased cognitive function are closely related to OSAS, and it may result in excessive daytime sleepiness, which is associated with traffic accidents (2-4).

Although OSAS is found in approximately 1%-5% of adults, the actual incidence is estimated to be higher, and as a chronic disease, it has become a public health problem (5, 6). The gold standard diagnostic method for OSAS is a full-night polysomnography (PSG) (7). Definitive diagnosis of OSAS through a clinical evaluation alone is impossible. However, an adequate evaluation combined with an easily accessible test would be a useful way to direct the appropriate patients to sleep centers in circumstances with a limited opportunity for PSG. Owing to insufficient PSG laboratories, appointment lists for PSG are quite long. For this reason, it is necessary to use an alternative diagnostic method instead of PSG or a screening method prior to PSG evaluation.

Pulse oximetry is a method designed to screen for OSAS because it is inexpensive, easy to use, and does not require a specialist for evaluation. Another possible method relies on the proven role of obesity in the etiopathogenesis of OSAS; the severity of obesity can be determined using body mass index (BMI) (8). The aim of the present study was to investigate whether the use of BMI and pulse oximetry is sufficient to predict the severity of OSAS without a PSG evaluation.

Methods

In this retrospective study, we analyzed the medical records and PSG data of 994 patients who were admitted to a tertiary referral center with complaints of witnessed apnea, excessive daytime sleepiness, and snoring between April 2008 and September 2016. A total of 956 patients were included in the study after 38 patients with a waking arterial oxygen saturation <90% were excluded.

Full-night PSG (Alice 5; Philips Respironics, The Netherlands) was performed under the supervision of a sleep technician during spontaneous sleep. Electroencephalogram, submental and bilateral tibialis anterior electromyograms, electrooculogram, nasal airflow, thoracic and abdominal respiratory efforts, blood oxygen saturation (pulse oximetry), and body positions were recorded. An ENT physician who had a certificate in PSG and sleep disorders scored the PSG data manually according to the standard criteria of the American Academy of Sleep Medicine. Apnea was defined as total cessation of airflow for at least 10 s. Hypopnea was defined as a 50% decrease (from baseline) in airflow or chest wall movement accompanied by an oxygen desaturation of 3%. The apnea-hypopnea index (AHI) was defined as the number of apneas and/or hypopneas recorded during the study per hour of sleep (9).

Patients were classified into four groups according to the PSG monitoring results: simple snoring group (AHI<5), mild OSAS group (5≤AHI<15), moderate OSAS group (AHI15≤AHI<30), and severe OSAS group (AHI≥30).

ST_{90} was defined as duration of sleep with oxygen saturation <90% (min) and Min $O_2$was defined as minimum O_2 saturation (%).

The study was approved by the local ethics committee and was conducted in accordance with the ethical principles of the Declaration of Helsinki (project no.: 1117-2016). Informed consent was not received due to the retrospective nature of the study.

Statistical Analysis

Number Cruncher Statistical System (NCSS) 2007 & Power Analysis and Sample Size (PASS) 2008 statistical software (UT, USA) was used for data analysis. Results were expressed using descriptive statistics as mean±standard deviation (SD), median±SD, frequency, ratio, minimum, and maximum. The Shapiro–Wilk test was used for analysis of the normal distribution of data. The Student's t-test was used for comparison of the groups with normal distribution of continuous variables, whereas the Mann-Whitney U test was used for comparison of two groups without normal distribution. The Pearson chi-square test was used for comparison of qualitative data. Diagnostic scan tests (sensitivity, specificity, positive predictive value, negative predictive value, and receiver operating characteristic curve analysis) were used for evaluation of the cut-off parameters. Logistic regression analysis was used for determination of the level of impact of risk factors on the presence of severe OSAS. A p value <0.05 was considered statistically significant.

Results

A total of 956 patients, 640 (66.9%) males and 316 (33.1%) females were included in the study. Simple snoring group consisted of 154(16.1%) patients. Mild OSAS group consisted of 223 (23.3%). Moderate OSAS group consisted of 205 (21.4%) patients. Severe OSAS group consisted of 374 (39.1%) patients. Table 1 shows the descriptive characteristics of the patients and their PSG findings. Based on the presence of severe OSAS, the cut-off points were ≥31.7 kg/m^2 for BMI, <81% for minimum oxygen saturation (Min O_2), and ≥14.1 min for sleep time with oxygen saturation <90% (ST_{90}) (Table 2).

Cut-off values determined by logistic regression analysis for BMI, Min O_2, and ST_{90} showed that the effects of these variables on severe OSAS presence retained their significance in a multivariate analysis. Each variable had p=0.001 (OR: 1.808; 95% CI: 1.258–2.600 for BMI, OR: 2.665; 95% CI: 1.760–4.038 for Min O_2, and OR: 9.887; 95% CI: 6.522–14.987 for ST_{90}).

Severe OSAS risk was higher in patients with BMI ≥31.7 kg/m^2 than in those without (OR: 3.324; 95% CI: 2.506–4.409, p=0.001).

Severe OSAS risk was higher in patients with Min O_2 ≤81% than in those without (OR: 11.108; 95% CI: 8.155–15.129, p=0.001).

Severe OSAS risk was higher in patients with ST_{90} ≥14.1 min than in those without (OR: 19.539; 95% CI: 14.001–27.267, p=0.001).

Severe OSAS risk was higher in patients with BMI ≥31.7 kg/m^2 and Min O_2 ≤81% than in those without (OR: 20.049; 95% CI: 13.096–30.695, p=0.001).

Table 1. Demographic characteristics and polysomnography findings in patients

Variables		Min–max (median)	Mean±SD
Age (year)		18–81 (51)	50.35±11.31
BMI (kg/m^2)		18.5–54.1 (29.8)	30.20±4.88
AHI		0–125.5 (20.1)	29.96±27.62
Min O_2		20–95 (83)	78.81±12.18
ST_{90}		0–461.5 (6.2)	40.68±78.34
		n	%
Gender	Female	316	33.1
	Male	640	66.9
Level of OSAS	Simple snoring	154	16.1
	Mild OSAS	223	23.3
	Moderate OSAS	205	21.4
	Severe OSAS	374	39.1

AHI: apnea–hypopnea index; ST_{90}: duration of sleep with oxygen saturation <90% (min); Min O_2: minimum O_2 saturation (%); BMI: body mass index; OSAS: obstructive sleep apnea syndrome

Table 2. Determination of cut-off scores and diagnostic scan tests (sensitivity, specificity, PPV, NPV, and AUC) for patients

Variables		Cut-off	Sensitivity %	Specificity %	PPV	NPV	AUC	95% CI	p
Total	BMI	≥31.7	48.13	78.18	58.63	70.11	0.661	0.625-0.696	0.001**
	Min O_2	≤81	77.54	76.29	67.76	84.09	0.851	0.827-0.875	0.001**
	ST_{90}	≥14.1	76.47	85.74	77.51	85.01	0.882	0.861-0.904	0.001**
Female	BMI	≥32.3	56.07	71.29	50.00	76.02	0.670	0.608-0.733	0.001**
	$MinO_2$	≤81	82.24	69.86	58.28	88.48	0.849	0.807-0.891	0.001**
	ST_{90}	≥14.4	76.64	84.21	71.30	87.56	0.888	0.852-0.924	0.001**
Male	BMI	≥31.7	43.45	84.99	67.44	67.74	0.673	0.631-0.716	0.001**
	$MinO_2$	≤82	80.90	76.41	71.05	84.82	0.856	0.827-0.885	0.001**
	ST_{90}	≥14.1	76.40	86.60	80.31	83.68	0.881	0.854-0.908	0.001**

**p<0.01
PPV: positive predictive value; NPV: negative predictive value; AUC: area under the curve; ST_{90}: duration of sleep with oxygen saturation <90% (min); MinO2: minimum O_2 saturation (%); BMI: body mass index

Table 3. Cut-off values determined by logistic regression analysis for BMI, Min O2, and ST90 based on the presence of severe OSAS

Cut-off	OR (95 CI%)	p	Sensitivity %	Specificity %	Accuracy %
BMI≥31.7	3.324 (2.506-4.409)	<0.001**	48.13	78.18	66.42
$MinO_2$≤81	11.108 (8.155-15.129)	<0.001**	77.54	76.29	76.78
ST_{90}≥14.1	19.539 (14.001-27.267)	<0.001**	76.47	85.74	82.11
BMI≥31.7+$MinO_2$≤81	20.049 (13.096-30.695)	<0.001**	40.91	91.58	71.76
BMI≥31.7+ST_{90}≥14.1	30.242 (19.079-47.937)	<0.001**	38.77	93.64	72.18
$MinO_2$≤81+ST_{90}≥14.1	29.004 (19.767-42.558)	<0.001**	71.93	90.03	82.95
BMI≥31.7+$MinO_2$≤81+ST_{90}≥14.1	37.173 (22.465-61.510)	<0.001**	37.70	94.85	72.49

**p<0.01
OSAS: obstructive sleep apnea syndrome; ST_{90}: duration of sleep with oxygen saturation <90% (min); Min O_2: minimum O_2 saturation (%); BMI: body mass index

Severe OSAS risk was higher in patients with BMI ≥31.7 kg/m^2 and ST_{90} ≥14.1 than in those without (OR: 30.242; 95% CI: 19.079–47.937, p=0.001).

Severe OSAS risk was higher in patients with Min O_2 ≤81% and ST_{90} ≥14.1 min than in those without (OR: 29.004; 95% CI: 19.767–42.558, p=0.001).

Severe OSAS risk was higher in patients with BMI ≥31.7 kg/m^2, ST_{90} ≥14.1 min, and Min O_2 ≤81% than in those without (OR: 37.173; 95% CI: 22.465–61.510, p=0.001).

Sensitivity (37.70%), specificity (94.85%), and accuracy (72.49%) of the three cut-off scores were shown in Table 3.

Both male and female patients were evaluated (Tables 2, 4, and 5). Based on the presence of severe OSAS in female patients, the cut-off points were ≥32.3 kg/m^2 for BMI, <81% for Min O_2, and ≥14.4 for ST_{90} (Table 2). Severe OSAS risk was higher in female patients with BMI ≥32.3 kg/m^2, ST_{90} ≥14.1, and Min O_2 ≤81% than in those without (OR: 33.994; 95% CI: 14.405–80.223, p=0.001). Sensitivity (45.79%), specificity (92.34%), and accuracy (76.58%) of the three cut-off scores were shown in Table 4.

Based on the presence of severe OSAS in male patients, the cut-off points were ≥31.7 kg/m^2 for BMI, <82% for Min O_2, and ≥14.1 min for ST_{90} (Table 2). Severe OSAS risk was higher in male patients with BMI ≥31.7 kg/m^2, ST_{90} ≥14.1, and Min O_2≤82% than in those without (OR: 53.077; 95% CI: 26.676–105.606, p=0.001). Sensitivity (34.46%), specificity (96.51%), and accuracy (70.63%) of the three cut-off scores were shown in Table 5.

Discussion

In the present study, we demonstrated that a combination of BMI and pulse oximetry data might provide accurate results for predicting OSAS in cases where it is difficult to access PSG and in circumstances where large populations need to be screened for OSAS.

Polysomnography is widely accepted as the gold standard test for diagnosis of OSAS. It requires expensive equipment, the presence of a technician and a specialized doctor, and is very time consuming, making the procedure difficult. In addition to increasing awareness of preventive care services for OSAS, individuals are increasingly referred to sleep clinics for sleep-related diseases due to increasing global BMI. However, since there are insufficient laboratories to respond to these increasing demands

Table 4. Cut-off values determined by logistic regression analysis for BMI, Min O_2, and ST_{90} in female patients based on the presence of severe OSAS

Cut-off	OR (95 CI%)	p	Sensitivity %	Specificity %	Accuracy %
BMI≥32.3	3.170 (1.951-5.151)	<0.001**	56.07	71.29	66.14
$MinO_2$≤81	10.734 (6.027-19.116)	<0.001**	82.24	69.86	74.05
ST_{90}≥14.4	17.493 (9.775-31.307)	<0.001**	76.64	84.21	81.65
BMI≥32.3+$MinO_2$≤81	17.893 (8.531-37.531)	<0.001**	50.47	87.56	75.00
BMI≥32.3+ST_{90}≥14.4	23.800 (11.163-50.740)	<0.001**	45.79	90.43	75.32
$MinO_2$≤81+ST_{90}≥14.4	24.864 (12.683-48.744)	<0.001**	73.83	86.60	82.28
BMI≥32.3+$MinO_2$≤81+ST_{90}≥14.4	33.994 (14.405-80.223)	<0.001**	45.79	92.34	76.58

**p<0.01

OSAS: obstructive sleep apnea syndrome; ST_{90}: duration of sleep with oxygen saturation <90% (min); Min O_2: minimum O_2 saturation (%); BMI: body mass index

Table 5. Cut-off values determined by logistic regression analysis for BMI, Min O2, and ST90 in male patients based on the presence of severe OSAS

Cut-off	OR (95 CI%)	p	Sensitivity %	Specificity %	Accuracy %
BMI≥31.7	4.349 (2.994-6.316)	<0.001**	43.45	84.99	67.66
$MinO_2$≤82	13.717 (9.309-20.211)	<0.001**	80.90	76.41	78.28
ST_{90}≥14.1	20.918 (13.875-31.536)	<0.001**	76.40	86.60	82.34
BMI≥31.7+$MinO_2$≤82	28.504 (16.283-49.899)	<0.001**	37.83	93.30	70.16
BMI≥31.7+ST_{90}≥14.1	43.102 (22.823-81.403)	<0.001**	35.21	95.98	70.63
$MinO_2$≤82+ST_{90}≥14.1	34.812 (21.504-56.354)	<0.001**	74.16	90.88	83.91
BMI≥31.7+$MinO_2$≤82+ST_{90}≥14.1	53.077 (26.676-105.606)	<0.001**	34.46	96.51	70.63

OSAS: obstructive sleep apnea syndrome, ST_{90}: duration of sleep with oxygen saturation <90% (min), Min O_2: minimum O_2 saturation (%), BMI: body mass index

worldwide, it is necessary to be selective when determining which people should be sent to sleep laboratories (10-12).

Although the etiopathogenesis of OSAS is not clearly understood, hypoxia, obesity, and inflammation are the most important suspected factors (2, 4, 13). Approximately 2 billion people worldwide are overweight, and the incidence of obesity is >20% in Western countries (14). The relationship between obesity and OSAS is complex. Obesity predisposes to OSA, and the prevalence of OSA is increasing because of the ongoing epidemic of obesity. It is a vicious circle (15). It is estimated that 70% of patients with OSA are obese, and conversely, the prevalence of OSA in obese individuals is approximately 40% to 70% (16, 17). Although BMI alone does not definitively predict OSAS, it may provide useful information combined with other clinical data.

Pang et al. (18) found that the mean BMI is 32.9 kg/m^2, and the mean AHI is 37.9 event/hour. They also reported a significant correlation between BMI and AHI. Similarly, Sarı et al. (11) reported a significant correlation among BMI, neck circumference, and AHI, especially in male patients with OSAS. For this reason, they concluded that the assessment of BMI and neck circumference can contribute to the diagnosis of OSAS.

The European OSAS Working Group recommends the use of advanced diagnostic tests in issuing a driver's license if an individual has a BMI ≥35 kg/m^2 and a complaint of excessive daytime sleepiness (19). In other countries, PSG is obligatory for individuals with a BMI ≥33 kg/m^2, regardless of whether they complain of excessive daytime sleepiness (20). However, OSAS is not found in every obese patient. Owing to this, directing every obese patient to PSG will lead to unnecessary examinations. This means increasing costs and wasted resources.

As adverse changes in AHI and arterial oxygen saturation increase, comorbid diseases and conditions associated with OSAS increase. In particular, hypoxia is one of the most important factors in the etiopathogenesis of OSAS. As hypoxia that occurs during sleep deepens and lasts longer, damage occurs in organs, such as the brain, heart, and vascular system. Therefore, it is important to use Min O_2 and ST_{90} values in the assessment of OSAS (1, 21).

Pulse oximetry is a relatively simple, feasible, and inexpensive method that has been extensively studied in sleep clinics as a way to routinely assess patients' oxygen saturation during sleep. Various desaturation indexes and threshold values for oxygen saturation have been used to predict OSAS with data obtained from pulse oximetry (22, 23). Gyulay et al. (24) reported that pulse oximetry has 40% sensitivity and 98% specificity in patients with AHI ≥15 and >4% desaturation index, and that patients who meet these criteria should be treated with continuous positive airway pressure. In another study, although there was a possible negative effect on case selection of patients with OSAS

due to false positive results, pulse oximetry was reported to be a useful diagnostic tool in patients with OSAS (25). On the other hand, there are studies in the literature reporting that pulse oximetry is not sufficiently sensitive and specific as a diagnostic tool for OSAS (26). One study reported that abnormal pulse oximetry has a specificity of 97% in children with suspected OSAS, but normal pulse oximetry cannot exclude the diagnosis of OSAS (27). Furthermore, sleep-disordered breathing events can lead to sleep deprivation without causing arterial desaturation, and they cannot be detected by pulse oximetry (28).

In the present study, we investigated the relationship among BMI, Min O_2, and ST_{90} values and OSAS to determine if severe OSAS (AHI ≥30) was present. We aimed to find predictive values for patients with severe OSAS because of the large number of morbidities and the fact that it is a group of patients requiring treatment. We found that OSAS correlates the most with ST_{90} and Min O_2 values when we evaluate for a single criterion. These results offer evidence that the severity and, more importantly, the duration of hypoxia are the most relevant parameters in OSAS. A new parameter, obtained by correlating the AHI with the ST_{90} and Min O_2 values, may be more useful for determining the severity of OSAS. We also found that BMI values are correlated with OSAS. In addition, the likelihood of individuals who met all three cut-off scores with OSAS increased significantly, and it had a specificity of approximately 95%. Another advantage of pulse oximetry is that it is possible for patients to perform this evaluation in their own home where they always sleep, thereby increasing compliance with the evaluation and obtaining more accurate results. These results suggest that a pulse oximetry device that is small in size and weight and easy to integrate with smartphones may be highly suitable for screening patients with severe OSAS. Therefore, we suggest the following procedure for screening patients with severe OSAS. A pulse oximetry should be advised to patients with a BMI >32 kg/m^2 and with complaints of OSAS. Then, if Min O_2 is <81%, and ST_{90} is >14 min, the patient may be considered as severe OSAS. On the other hand, continuous monitoring and recording of pulse oximetry still require instrumentation. Furthermore, the results of the present study are not a substitute for PSG but used to screen patients who would need PSG. PSG is still the gold standard test for diagnosis and evaluation of OSAS.

The results of the present study may not be capable of representing the general population because we included only patients with witnessed apnea, excessive daytime sleepiness, and snoring. Additionally, this circumstance caused a decrease in sensitivity ratios we obtained according to the cut-off values we found. If patients from the general population without complaints of OSA had been included in the study, the sensitivity ratios for the cut-off values would have been higher. On the other hand, with the specificity of 95% we obtained according to the cut-off values in the present study, false positive results were obtained in as much as 5% of the patients without severe OSA. Another superiority of our study is the large number of patients.

Conclusion

The present study suggests that the appropriate cut-off values obtained from combining BMI and pulse oximetry data can provide accurate results for predicting severe OSAS with high specificity.

Ethics Committee Approval: Ethics committee approval was received for this study from the Ethics Committee of Ankara Numune Training and Research Hospital (1117-2016)

Informed Consent: Informed consent was not received due to the retrospective nature of the study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - R.O.K., F.C.S.K., D.B., N.Y.K., İ.G., Y.F.Y., M.Ö.; Design - R.O.K., F.C.S.K., D.B., N.Y.K., İ.G., Y.F.Y., M.Ö.; Supervision - R.O.K., F.C.S.K., D.B., N.Y.K., İ.G., Y.F.Y., M.Ö.; Resource - R.O.K., F.C.S.K., N.Y.K., İ.G., D.B.; Materials - R.O.K., F.C.S.K., N.Y.K.; Data Collection and/or Processing - R.O.K., F.C.S.K., N.Y.K.; Analysis and/or Interpretation - R.O.K., F.C.S.K. İ.G., D.B., Y.F.Y.; Literature Search - R.O.K., F.C.S.K. İ.G., D.B.; Writing - R.O.K., F.C.S.K., N.Y.K., M.Ö.; Critical Reviews - N.Y.K., Y.F.Y., M.Ö.

Conflict of Interest: The authors have no conflicts of interest to declare.

Financial Disclosure: The authors declared that this study has received no financial support.

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