During economic crisis can sleep questionnaires improve the value of oximetry for assessing sleep apnea?

Athanasia Pataka[1], Paul Zarogoulidis[1], Wolfgang Hohenforst-Schmidt[2], Theodora Tsiouda[1], Drosos Tsavlis[1], Ioannis Kioumis[1], Elene Papakala[1], Ilias Karapantzos[3], Chrysa Karapantzou[3], Aggeliki Rapti[4], Kosmas Tsakiridis[1], Konstantinos Zarogoulidis[1], Parakevi Argyropoulou[1]

[1]Pulmonary Department, "G. Papanikolaou" General Hospital, Aristotle University of Thessaloniki, Thessaloniki, Greece; [2]Medical Clinic I, "Fuerth" Hospital, University of Erlangen, Fuerth, Germany; [3]Ear, Nose and Throat Department, "Saint Luke" Private Hospital, Panorama, Thessaloniki, Greece; [4]Second Pulmonary Clinic, "Sotiria" Chest Diseases Hospital, Athens 11527, Greece

Contributions: (I) Conception and design: A Pataka, P Argyropoulou; (II) Administrative support: A Pataka, P Zarogoulidis; (III) Provision of study materials or patients: A Pataka, P Zarogoulidis, P Argyropoulou; (IV) Collection and assembly of data: A Pataka, P Zarogoulidis; (V) Data analysis and interpretation: A Pataka, W Hohenforst-Schmidt, T Tsiouda, D Tsavlis; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

Correspondence to: Paul Zarogoulidis, MD, PhD. Pulmonary Department, "G. Papanikolaou" General Hospital, Aristotle University of Thessaloniki, Thessaloniki, Greece. Email: pzarog@hotmail.com.

Background: The diagnosis of obstructive sleep apnea/hypopnea syndrome (OSAHS) is essential but polysomnography (PSG) is expensive and time consuming. Oximetry has been used as a less expensive indicator of OSAHS. The aim of the study was to evaluate the clinical utility of the combination of oximetry with four different questionnaires: Stop, Stop Bang (S-B), Berlin questionnaire (BQ), Epworth Sleepiness Scale (ESS) in order to identify patients at risk for OSAHS compared with in-laboratory PSG.

Methods: Patients visiting a sleep clinic were prospectively studied. They completed Stop, S-B, BQ and ESS. Home oximetry and in laboratory PSG were performed within 3–20 days.

Results: A total of 204 patients were included in the study (77.5% males, mean age 51.8±13.8 years, BMI 32.8±6.2 kg/m^2, SaO_2% awake 95.7±2). S-B had the highest sensitivity (Se) (97.5%) and negative predictive value (NPV) (62.5%) but the lowest specificity (Sp) (9%), whereas ESS had the best Sp (75%) and positive predictive values (PPV) (81.4%). The predictive values of questionnaires improved as the severity of OSAHS worsened. The predictive values of oximetry were high for severe but low for mild and moderate OSAHS. For that oximetry was combined with different sleep questionnaires in different OSAHS severity groups, but with no improvement in the predictive values.

Conclusions: Oximetry may be used as a tool for identifying severe OSAHS. For mild and moderate disease the combination of questionnaires did not improve the diagnostic accuracy and especially for symptomatic patients with negative results, the need of PSG is essential.

Keywords: Oximetry; Epworth Sleepiness Scale (ESS); Stop; Stop-Bang (S-B); Berlin questionnaire (BQ); sleep apnea

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Introduction

The diagnosis of obstructive sleep apnea/hypopnea syndrome (OSAHS) is essential as OSAHS is an important cause of morbidity and mortality. As obesity is increasing, OSAHS prevalence and consequences will also increase. The "gold standard" for the diagnosis of OSAHS is polysomnography (PSG) but it is expensive, time consuming and the waiting lists of several sleep centres are rather long reaching sometime almost 1 year. In countries with economic problems, as Greece, more economic solutions are essential. For the identification of the patients with high OSAHS probability several questionnaires and clinical models have been used (1-3). However some patients may be misdiagnosed as the degree of heterogeneity between questionnaires and clinical prediction models is high (2,3). Oximetry has been used as less expensive indicator in the screening of OSAHS (1).

In a previous study we have demonstrated the clinical utility of five different questionnaires in a sleep clinic (4). The aim of this study was to evaluate the clinical utility of the combination of home oximetry and four different questionnaires: the Stop questionnaire, the Stop Bang (S-B) clinical scale, the Berlin questionnaire (BQ) and the Epworth Sleepiness Scale (ESS) in a sleep clinic of a tertiary hospital in order to identify patients with OSAHS compared with in-laboratory PSG.

Methods

A prospective study of the patients visiting the Sleep Clinic of the Respiratory Failure Unit of G Papanikolaou Hospital (2011–2014 Approved by our Investigational Review Board "G. Papanikolaou" number 357/23032010). Patients aged >18 years complaining of daytime sleepiness were included. The exclusion criteria were refusal to participate, known sleep disorder, respiratory insufficiency, chronic obstructive pulmonary disease (COPD), heart failure, severe anemia, inability to use the equipment or living >50 km from the hospital. The protocol had been approved by the ethical review board. All participants were asked to give written, informed consent approved by the Local Ethics Committee.

All the participants answered the ESS, the BQ and the Stop questionnaire during their first visit. The S-B was also calculated. Body mass index (BMI), age, neck circumference and gender were documented by a sleep technician.

The ESS (5) measures sleep propensity in order to identify excessive daytime sleepiness (EDS) in which the subject rates on a scale of 0 to 3 the chances of dozing in eight different situations commonly met in daily life (sum between 0 to 24). Abnormal sleepiness is considered when scores are above 10.

The Stop questionnaire (6) consists of four questions related to snoring, tiredness during daytime, observed apneas and high blood pressure (Stop). When ≥2 questions are answered positively, there is a high risk for OSAHS. The BANG portion is estimated by assessing BMI >35 kg/m^2, age (>50 years old), neck circumference (>40 cm) and gender (male). Zero point is assigned for each negative answer and 1 for each positive answer. When ≥3 of the 8 questions are answered positively there is a high risk for OSAHS and when ≤2 a low risk (7).

The BQ identifies individuals at higher risk of having OSAHS (8). It includes three categories (10 questions) about: (I) snoring severity (items 1–5); (II) EDS (items 6–9) and (III) history of hypertension or obesity (item 10). Categories 1 and 2 are positive when the sum of all items is ≥2. When there are persistent symptoms (>3–4 times/week) in categories 1 and 2 and hypertension (≥140/90 mmHg or use of medication) or BMI ≥30 kg/m^2 in category 3 there is high risk for OSAHS. If a patient scores positive in only one or none of the categories then is classified as in low risk whereas if a patient scores positive in two or more categories then is classified as having high risk for OSAHS.

Witnessed apneas were defined as observed breathing pauses during sleep documented from the participant or a household member (nearly every day, 3–4 times/week, 1–2 times/week, 1–2 times/month, never or nearly never).

Continuous nocturnal SpO_2 monitoring at home was obtained with a type III recording system (SOMNOcheck, Weinmann). For this study we used only the finger pulse oximeter allowing the measurement of transcutaneous oxygen saturation (SpO_2) and pulse wave signal. Patients were educated by a trained technician for the application of the device, which took on average 15 min. They then took the device home with written instructions and applied the sensor unsupervised. The device was programmed to initiate the recording at 12 A.M. and stop the recording at 6 A.M. The device was returned the next day and the data were analyzed by a sleep technician. Oxygen desaturation index (ODI) was defined as the number of scored desaturations >4% by the time in bed (9). A manual event-by-event interpretation was performed using the continuous real SpO_2 signal using a 2-min window display resolution. A sawtooth waveform pattern, i.e., progressive desaturation

followed by a rapid increase in SpO_2 was suggestive of OSAHS (9).

In-laboratory PSG (Alice 5 Diagnostic Sleep System, Philips Respironics) was performed in all the participants using electroencephalography (EEG), submental electromyography (EMG), electrooculography (EOG), electrocardiography (ECG), microphone on anterior neck for snoring detection, oronasal thermistor and nasal pressure transducer for airflow limitation detection , thoracic and abdominal respiratory effort bands, body position detection and oximetry. PSGs were manually scored according the American Academy of Sleep Medicine (AASM) guidelines (10). Apnea hypopnea index (AHI) was calculated as the number of apneas and hypopneas per hour of sleep. Apnea was defined as the drop of airflow ≥90% of baseline for at least 10 second and hypopnea as a decrease in airflow of at least 30% for at least 10 second with oxygen desaturation of ≥4% from pre-event baseline. Obstructive apneas were defined by the absence of airflow, but the persistence of respiratory effort. The severity of OSAHS was determined by the AHI: 5–15 as mild; greater than 15 to 30 as moderate; greater than 30 as severe (11). PSG and oximetry were performed in random order and within a time interval of 4–30 days.

Manual analysis of each patient's studies (PSG, oximetry) was performed by a single person who was blinded to the origin of the data. The same analyst scored all studies manually in batches and in unnamed format so that was blinded to results. Home oximetry tracings were considered adequate if the patients reported sleeping more than 4 h and a second home recording was performed, if the recording was not adequate or the traces were unacceptable.

Statistical analysis

SPSS version 17.0 (SPSS Science, Apache Software Foundation, Chicago, IL, USA) was used. The Pearson correlation coefficient was used to evaluate if there was a significant correlation between different questionnaires in all the population studied and in different risk groups. For nonparametric variables Spearman's correlation coefficient was used. The chi-square test was used for categorical variables. Separate bivariate logistic regression models were used to determine the odds ratio (OR) in predicting OSAHS. The discriminatory ability of each questionnaire or oximetry for diagnosing OSAHS was evaluated using receiver operating characteristic (ROC) curves. Analysis of variance (ANOVA) with post hoc contrasts by *t* tests for continuous variables (Bonferroni) was used to analyze the differences between group means. For non-normally distributed data the Kruskal-Wallis test was used. Tests were two-tailed and $P<0.05$ was accepted as statistically significant. Data were presented as mean ± SD unless otherwise stated. The power of the study was estimated to be 90% of detecting a Cohen's effect size f^2 of 0.1 given a sample size of 168 patients and α error probability of 0.05. We involved more patients in order to avoid missing data. Sensitivity (Se), specificity (Sp), positive predictive value (PPV), negative predictive value (NPV), positive and negative likelihood ratios (LR+/LR–) were calculated. Combined Se and Sp was also estimated as used in our prior study (4) to evaluate the combination of oximetry with different questionnaires. To evaluate the effectiveness of a combination of questionnaires and oximetry, the serial strategy (the combination is positive if all tests are positive and is negative if at least one test is negative) was conducted:

$$Se = Se1 \times Se2 \times \cdots \times Sek$$
$$Sp = 1 - [(1 - Sp1) \times (1 - Sp2) \times \cdots \times (1 - Spk)]$$

Results

From the 240 patients that were initially recruited, 204 were included in the study (77.5% males, mean age 51.8± 13.8 years, BMI 32.8±6.2 kg/m^2, SaO_2% awake 95.7±2). Eight patients refused to complete both recordings, 28 patients refused to repeat the home recording as oximetry was not completed at home or the recording had a bad signal. Fourteen patients (included in the study) repeated the home oximetry recording for the reasons mentioned above. Patients' characteristics are presented in *Table 1*. In the post hoc analysis BMI differed significantly between no and severe, mild and severe and between moderate and severe OSAHS ($P<0.0001$), whereas neck circumference differed between no and severe ($P<0.0001$). AHI, ODI of PSG and ODI of oximetry (ODIox) did not differ significantly between no and mild OSAHS. The ESS did not differ between no and mild and between moderate and severe OSAHS. Stop differed significantly between no and severe and between mild and severe OSAHS, whereas S-B did not differ significantly between no and mild, mild and moderate and moderate and severe OSAHS. There was a good correlation between ODIox and ODI of PSG ($r=0.95$; $P<0.0001$) and between ODIox and AHI ($r=0.811$; $P<0.0001$). In *Table 2* the predictive parameters of different cut-offs of ODIox for AHI >15 and AHI >5 plus symptoms

Table 1 Characteristics of the subjects involved in the study

Characteristics	All	No OSAHS	Mild OSAHS	Moderate OSAHS	Severe OSAHS
Number	204	39 (19.1%)	29 (14.2%)	54 (26.5%)	82 (40.2%)
Sex (male/female)	158/46	30/9	23/6	40/14	65/17
Age (years) (mean ± SD)	51.8±13.8	48.5±17.4	50.3±12.6	55.4±13.7	51.5±11.8
BMI (kg/m^2) (mean ± SD)	32.8±6.2	29.2±5.2	30.95±4.65	31.6±5.2	35.9±6.25
Neck circumference (cm) (mean ± SD)	41.6±3.9	39.4±4.4	40.8±3.47	41.5±3.6	42.9±3.7
Waist to hip ratio	1.0±0.4	0.95±0.125	0.96±0.1	1.1±0.8	1.01±0.08
AHI	29.7±24.7	2.3±1.7	10.0±3.0	26.7±4.2	54.4±22.3
ODI/h PSG	27.8±22.3	6.0±4.5	12.0±6.3	24.5±12.3	52.9±22.2
ODI/h oximetry	23.5±20.1	3.9±3.2	10.7±7.2	22.3±11.5	45.7±20.5
Witnessed apneas (>3–4 days/week)	154 (71%)	19 (49%)	18 (62%)	41 (76%)	67 (82%)
Snoring (>3–4 days/week)	191 (94%)	32 (82%)	27 (93%)	53 (98%)	79 (97.5%)
ESS (mean ± SD)	10.3±5.3	8.25±5.5	6.7±4.2	11.3±4.9	11.6±5.2
ESS ≥11	86 (42%)	11 (28%)	5 (17.2%)	28 (52%)	42 (51%)
Berlin low risk	59 (29%)	23 (59%)	11 (38%)	15 (28%)	10 (12%)
Berlin high risk	145 (71%)	16 (41%)	18 (62%)	39 (72%)	72 (88%)
Stop (score) (mean ± SD)	2.9±0.85	2.5±1.0	2.54±0.7	3.0±0.85	3±0.74
Stop-Bang (score) (mean ± SD)	5.1±1.5	4.2±1.64	4.5±1.3	5.3±1.45	5.64±1.3

OSAHS, obstructive sleep apnea/hypopnea syndrome; BMI, body mass index; AHI, apnea hypopnea index; ODI, oxygen desaturation index; PSG, polysomnography; ESS, Epworth Sleepiness Scale. For post hoc analysis refer to results.

are presented. When AHI >15 was used for OSAHS diagnosis, ODIox ≥5 had the best Se and NPV, whereas ODIox ≥15 had the best Sp, PPV and area under the ROC curve (AUC).

The predictive parameters of ODIox for different categories of OSAHS severity are presented in *Table 3*. The predictive values improved as the severity of OSAHS worsened, especially for ODI ≥15. However, the predictive values of oximetry were low especially for mild and then for moderate OSAHS. For that we attempted to combine different sleep questionnaires with oximetry in order to improve the predictive value of oximetry in mild and moderate OSAHS. The predictive values of ESS, BQ, Stop and S-B for AHI >15, ODIox ≥5 and ODIox ≥15 are presented in *Table 4*. S-B had the highest Se and NPV but the lowest Sp, whereas ESS had the best Sp and PPV (*Table 5*). No significant differences existed when patient were evaluated according to sex or age. The predictive values of the presence of witnessed apneas (>3–4/week) for AHI >15 were: Se: 85%, Sp: 39.4%, PPV: 74.4%, NPV: 55.8%, LR(+)/(–): 1.4/0.4, OR: 3.7 (range, 1.8–7.5). Additionally for mild OSAHS the presence of witnessed apneas only, had Se: 73%, Sp: 22%, PPV: 13.5%, NPV: 83.3%, LR(+)/(–): 0.94/1.2. We combined different questionnaires with ODIox ≥15 for different categories of OSAHS severity (*Table 6*). The combination of different questionnaires with ODIox ≥15 did not improve the Se and Sp neither of questionnaires nor of oximetry especially in mild and moderate disease. In severe OSAHS the predictive values of oximetry alone were high with high Se (97.5%), Sp (72.6%) and AUC [0.85, 95% CI (confidential interval): 0.8–0.9] (*Table 3*). These values did not further improve with the addition of questionnaires. Additionally, the low predictive values, especially in mild disease, also did not show any improvement with any combination (*Table 6*).

Discussion

In this study we found that oximetry can identify the presence of severe OSAHS and can be used as a simple

Table 2 Predictive values for different cut-offs of ODIox for AHI >15 and AHI >5 plus symptoms

Predictive values	ODI ≥5	ODI ≥10	ODI ≥15
AHI >15			
Se (%)	99.2	97.0	82.0
Sp (%)	60.3	78.0	94.0
PPV (%)	83.2	89.7	96.5
NPV (%)	97.6	93.0	72.7
Probability (+)/(–) (%)	79.3/20.7	72/28	56/44
LR(+)/(–)	2.5/0.01	4.4/0.04	14/0.2
OR (95% CI)	203.5 (26.8–1,543.7)	115.7 (36.7–364.8)	74 (24.6–222.8)
AUC (95% CI)	0.8 (0.70–0.87)	0.875 (0.80–0.94)	0.9 (0.83–0.93)
AHI >5 plus symptoms			
Se (%)	94.5	86.5	69.0
Sp (%)	84.6	89.7	95.0
PPV (%)	96.3	97.2	98.2
NPV (%)	78.6	61.4	42.0
Probability (+)/(–) (%)	79/21	72/28	56.6/43.7
LR(+)/(–)	6.10/0.06	8.40/0.15	13.40/0.32
OR (95% CI)	94 (31–284)	56 (18–174)	41 (9.5–176.6)
AUC (95% CI)	0.89 (0.83–0.97)	0.88 (0.82–0.95)	0.82 (0.75–0.90)

ODI, oxygen desaturation index; ODIox, ODI of oximetry; AHI, apnea hypopnea index; Se, sensitivity; Sp, specificity; PPV, positive predictive value; NPV, negative predictive value; LR, likelihood ratio; OR, odds ratio; CI, confidential interval; AUC, area under the ROC curve.

diagnostic test to identify patients at high risk in order to reduce the number of PSGs in countries with limited resources. The cost of oximetry in Greece is 8.8€ and that of PSG 146.7€. The waiting list of our sleep laboratory is long (9 months) and the need of a faster and cheaper diagnosis is essential. The Se of oximetry at different cut off points ranged between 99% (ODI ≥5) and 82% (ODI ≥15) for AHI >15, while Sp varied between 60% (ODI ≥5) and 94% (ODI ≥15). However the predictive values of oximetry were low especially for ODI ≥15 in mild and moderate OSAHS (*Table 3*). For that we combined different questionnaires with oximetry in order to evaluate whether the predictive values improved. In a previous study (4), we retrospectively evaluated different questionnaires in order to identify patients at risk for OSAHS in a sleep clinic and we combined different questionnaires with no significant improvement in their predictive values. In the present study we also did not find an improvement in the predictive values when we combined different questionnaires with oximetry especially in mild and moderate OSAHS (*Table 6*).

OSAHS is associated with a wide range of medical consequences, including cardiovascular morbidity that has been found to be associated with oxygen desaturation (12). Many patients with OSAHS have minimal or no symptoms or have a misperception of their symptoms. It is not clear if asymptomatic or minimally symptomatic patients with mild or moderate OSAHS have the same cardiovascular risk with those with symptoms. If they do not, then the detection of only the clinically symptomatic patients with the help of questionnaires may be adequate (13). Additionally patients with excessive sleepiness are more likely to respond to treatment (14).

The main limitation of our study was that it was based on the patients visiting a sleep clinic, not the general population. However in Greece frequently the role of a tertiary hospital is that of a primary care centre as the

Table 3 Predictive parameters of ODIox for different categories of OSAHS severity

Predictive parameters	Mild	Moderate	Severe
ODI ≥5			
Se (%)	65.0	98.0	100.0
Sp (%)	16.6	27.9	36.0
PPV (%)	11.9	31.6	52.2
NPV (%)	73.7	97.6	100.0
Probability (+)/(–) (%)	81/19	78.7/21.3	79/21
LR (+)/(–)	0.8/2.1	1.36/0.07	1.56/0
OR (95% CI)	0.4 (0.16–0.9)	18.9 (2.5–141.8)	2.1 (1.7–2.5)
AUC (95% CI)	0.4 (0.29–0.5)	0.63 (0.55–0.71)	0.68 (0.6–0.75)
ODI ≥10			
Se (%)	34.5	90.0	100.0
Sp (%)	19.5	34.7	48.7
PPV (%)	6.8	31.9	57.7
NPV (%)	63.5	91.0	100.0
Probability (+)/(–) (%)	74/26	71.6/28.4	71.3/28.7
LR (+)/(–)	0.43/3.35	1.38/0.3	1.95/0
OR (95% CI)	0.13 (0.05–0.30)	4.8 (1.8–12.8)	2.4 (1.95–2.87)
AUC (95% CI)	0.27 (0.16–0.38)	0.62 (0.54–0.71)	0.74 (0.67–0.80)
ODI ≥15			
Se (%)	3.4	56.0	97.5
Sp (%)	32.5	43.5	72.6
PPV (%)	0.87	25.2	71.4
NPV (%)	66.2	74.4	97.7
Probability (+)/(–) (%)	28/72	56.3/43.7	56.3/43.7
LR (+)/(–)	0.05/2.30	0.99/1.00	3.56/0.03
OR (95% CI)	0.017 (0.02–0.13)	0.98 (0.51–1.87)	106.2 (24.6–457.9)
AUC (95% CI)	0.18 (0.12–0.25)	0.498 (0.40–0.59)	0.85 (0.8–0.9)

ODI, oxygen desaturation index; ODIox, ODI of oximetry; OSAHS, obstructive sleep apnea/hypopnea syndrome; Se, sensitivity; Sp, specificity; PPV, positive predictive value; NPV, negative predictive value; LR, likelihood ratio; OR, odds ratio; CI, confidential interval; AUC, area under the ROC curve.

system of general practitioners is still not functional. So, the population visiting a sleep clinic is not always referred by a doctor. Several studies have shown that portable diagnosis and management of OSAHS in sleep centres may produce comparable patient outcomes with in laboratory sleep studies (15-17) and that the predictive values of oximetry in high risk populations as ours are high (18,19). The degree of oxygen desaturation varies between individuals depending on baseline arterial oxygen saturation, the presence or absence of lung disease and lung volumes (20-23). For that we excluded the patients with known respiratory insufficiency, sleep disorder,

Table 4 Predictive parameters for ESS, Berlin, Stop, Stop-Bang for AHI >15, ODI ≥10 and ODI ≥15

Predictive parameters	ESS	Berlin	Stop	Stop-Bang
AHI >15				
Se (%)	52.2	86.4	96.0	97.5
Sp (%)	75.0	37.9	8.8	8.9
PPV (%)	81.4	73.9	69.8	70
NPV (%)	42.8	57.9	50.0	62.5
Probability (+)/(–) (%)	43/57	78.4/21.6	94.5/5.5	95.5/4.5
LR (+)/(–)	2.1/0.6	1.4/0.36	1/0.45	1.1/0.27
OR (95% CI)	3.2 (1.7–6.3)	3.9 (1.8–8.2)	2.3 (0.64–8.30)	3.9 (0.9–16.9)
AUC (95% CI)	0.66 (0.60–0.74)	0.6 (0.5–0.7)	0.5 (0.40–0.62)	0.53 (0.4–0.6)
ODI ≥10				
Se (%)	48.2	84.7	95.4	96.9
Sp (%)	70.3	37.2	8.0	12.2
PPV (%)	81.2	76.6	73.0	74.2
NPV (%)	33.9	50.0	40.0	60.0
Probability (+)/(–) (%)	43/57	78.3/21.7	94.4/5.6	94.3/5.7
LR (+)/(–)	1.63/0.73	1.34/0.40	1.0/0.6	1.10/0.25
OR (95% CI)	2.2 (1.13–4.30)	3.3 (1.5–6.9)	1.8 (0.5–6.7)	4.3 (1.2–16.0)
AUC (95% CI)	0.6 (0.50–0.69)	0.6 (0.5–0.7)	0.5 (0.4–0.6)	0.5 (0.4–0.6)
ODI ≥15				
Se (%)	51.3	89.0	96.2	98.0
Sp (%)	67.8	36.0	7.9	10.6
PPV (%)	68.2	64.9	59.0	59.9
NPV (%)	51.0	71.0	60.0	80.0
Probability (+)/(–) (%)	43/57	78.3/21.7	94.5/5.5	94.4/5.6
LR (+)/(–)	1.6/0.7	1.4/0.3	1/0.5	1.1/0.2
OR (95% CI)	2.2 (1.24–4.00)	4.5 (2.1–9.9)	2.16 (0.6–7.9)	6 (1.2–29.0)
AUC (95% CI)	0.6 (0.52–0.70)	0.6 (0.5–0.7)	0.5 (0.43–0.60)	0.5 (0.45–0.6)

ESS, Epworth Sleepiness Scale; AHI, apnea hypopnea index; ODI, oxygen desaturation index; Se, sensitivity; Sp, specificity; PPV, positive predictive value; NPV, negative predictive value; LR, likelihood ratio; OR, odds ratio; CI, confidential interval; AUC, area under the ROC curve.

COPD or heart failure. Unfortunately we did not perform pulmonary function testing for all our patients. Another limitation of our study was that we only used ODI >4%. In the update of the 2007 AASM Manual for the Scoring of Sleep and Associated Events (24) ODI >3% was suggested for hypopnea definition but by that time we had already included 75 patients (24). The use ODI ≥3% instead of ≥4% desaturation for hypopnea definition could increase AHI substantially. OSAHS severity should be always interpreted according to the hypopnea definition employed. In the updated rules (24) the old hypopnea definition requiring ≥30% drop in flow for ≥10 seconds with ≥4%

Table 5 Predictive parameters for ESS, Berlin, Stop, Stop-Bang Screening Tool questionnaires for mild, moderate and severe OSAHS

Predictive parameters	ESS	Berlin	Stop	Stop-Bang
Mild OSAHS				
Se (%)	17.8	64.00	92.0	95.8
Sp (%)	53.0	18.50	5.0	6.0
PPV (%)	6.0	11.85	13.7	14.1
NPV (%)	79.3	75.00	80.0	90.0
LR (+)/(–)	0.40/1.55	0.80/1.95	0.97/1.50	1.10/0.69
AUC (95% CI)	0.36 (0.25–0.5)	0.4 (0.26–0.52)	0.5 (0.37–0.63)	0.51 (0.38–0.63)
OR (95% CI)	0.25 (0.09–0.70)	0.4 (0.16–1.00)	0.64 (0.13–3.20)	1.48 (0.18–12.20)
Moderate OSAHS				
Se (%)	51.0	75.0	93.4	90.1
Sp (%)	58.7	19.7	5.0	4.6
PPV (%)	29.8	24.4	25.3	24.0
NPV (%)	77.8	69.4	70.0	60.0
LR(+)/(–)	1.23/0.80	0.93/1.27	0.99/1.25	0.95/2.00
AUC (95% CI)	0.54 (0.4–0.64)	0.48 (0.37–0.58)	0.5 (0.4–0.6)	0.47 (0.37–0.58)
OR (95% CI)	1.48 (0.8–2.85)	0.74 (0.33–1.65)	0.79 (0.2–3.2)	0.48 (0.13–1.80)
Severe OSAHS				
Se (%)	52.4	94.4	97.4	98.7
Sp (%)	63.4	32.7	8.0	9.0
PPV (%)	51.2	50.0	44.7	45.7
NPV (%)	64.5	89.2	80.0	90.0
LR (+)/(–)	1.40/0.75	1.40/0.17	1.06/0.33	1.1/0.14
AUC (95% CI)	0.6 (0.50–0.69)	0.63 (0.55–0.72)	0.52 (0.43–0.61)	0.54 (0.45–0.62)
OR (95% CI)	1.9 (1.1–3.4)	8.25 (2.77–24.56)	3.23 (0.67–15.7)	7.6 (0.94–61.20)

ESS, Epworth Sleepiness Scale; OSAHS, obstructive sleep apnea/hypopnea syndrome; Se, sensitivity Sp, specificity; PPV, positive predictive value; NPV, negative predictive value; LR, likelihood ratio; AUC, area under the ROC curve; CI, confidential interval; OR, odds ratio.

desaturation may additionally be reported, as in our study. Additionally in the literature the BTS guidelines for oximetry used ODI 4% for assessing OSAHS (7). However it would be interesting to evaluate different ODI values and even the duration of desaturations with questionnaires in a future study.

In our study 80.8% of the patients were diagnosed with OSAHS by PSG which is higher than that of most of the previous studies (9,23). The majority of our patients had severe (40%) and moderate (26.5%) OSAHS. The sensitivities and specificities of oximetry were similar with other studies performed on sleep clinic populations (18,19) where the clinical suspicion of OSAHS is high. In a study of a population with low prevalence of OSAHS using clinical assessment and home oximetry a Se of 40% and a Sp of 98% were found for ODI >15 (25). In another study, the BTS pulse oximetry criteria had high Sp (100%) when positive, but rather low Se (31%) in patients with no significant desaturations but hypopneas (26). When we analysed the predictive values of oximetry according to the severity of the disease, they were very low in mild and then moderate OSAHS. Some of these patients, especially asymptomatic

Table 6 Combined sensitivities and specificities for the different questionnaires and ODIox ≥15

ODIox	OSAHS severity					
	Mild		Moderate		Severe	
	Se (%)	Sp (%)	Se (%)	Sp (%)	Se (%)	Sp (%)
S-B	3.3	36.55	50.4	46.1	96.20	75.0
ESS	0.6	66.25	28.6	76.7	51.00	89.9
BQ	2.2	45.00	42.0	45.4	92.00	81.6
ESS-S-B	0.6	70.20	25.7	77.7	50.42	90.9
S-B-ESS-BQ	0.4	75.70	19.3	82.1	47.39	93.9

ODIox, oxygen desaturation index of oximetry; OSAHS, obstructive sleep apnea/hypopnea syndrome; Se, sensitivity; Sp, specificity; S-B, Stop-Bang; ESS, Epworth Sleepiness Scale; BQ, Berlin Questionnaire.

with mild disease and no concomitant disease may not receive specific treatment but those with concomitant disease as hypertension or arrhythmias, OSAHS treatment may be essential.

In an attempt to improve these values we combined different questionnaires with oximetry but with no improvement in our findings. In the study of Pereira *et al.* (22) previously well-validated questionnaires were evaluated to diagnose or exclude OSAHS in combination with a level III portable monitor. They found that objective data from the portable monitor was superior to questionnaires in OSAHS diagnosis and that the use of questionnaires did not further enhance the diagnostic utility of the portable device. However, the accuracy and reliability of questionnaires vary depending on the patient population and the diagnostic AHI threshold used. The predictive values of BQ and S-B were similar with ours but with a lower Sp of S-B in our study. In the study of Silva *et al.* (27) ESS, Stop, S-B were evaluated in the general population with S-B having the highest Se (for respiratory disturbance index, RDI ≥15: 87.0% and for RDI ≥30: 70.4%). The sensitivities were higher in our study, whereas specificities were lower than in studies in the general population, possibly because our population was "preselected" with higher risk. Stop and S-B sensitivities were found to be high even in mild OSAHS, but their specificities were rather low. Se of BQ was good in our population, but Sp was low (28) possibly because of the selection of population. ESS is subjective, so it was not surprising that the Se was rather low and Sp moderate in our, as in other studies (28). Especially for mild OSAHS, the presence of witnessed apneas had better predictive values than ESS and similar with BQ. In our study we used only the oximetry of a type III device because thinking of the economic situation of our country we aimed to test an even less expensive device as oximetre than a type III device.

ODI has been used as a less expensive, sensitive indicator in the screening of severe OSAHS (7). In our study, there was a strong correlation between AHI and ODIox. However the use of questionnaires did not augment the diagnostic value of oximetry in moderate OSAHS where treatment is needed. Chai-Coetzer *et al.* (29) demonstrated that in primary care a simplified screening questionnaire (OSA50 score) followed by home oximetry can identify patients with moderate to severe OSAHS. Gurubhagavatula *et al.* (30) performed a two-stage method for OSAHS diagnosis using the MAP index and nocturnal oximetry in a sleep clinic population with a Se of 85%, Sp of 97%, PPV of 94% and NPV of 92% for an AHI >30/h. Mulgrew *et al.* (15) suggested a clinical algorithm for an ambulatory diagnosis and treatment of patients with high probability of OSAHS but with the caveat that patients with low probability in the diagnostic algorithm should undergo PSG. Our study was based in a sleep clinic population and it would be interesting to be performed in the general population in the future.

Apart from the increasing prevalence of OSAHS, obesity hypoventilation syndrome (OHS) is also likely to increase because of the global obesity epidemic. BMI >30 kg/m^2, chronic alveolar hypoventilation with daytime hypercapnia ($PaCO_2$ >45 mmHg), an increase in $PaCO_2$ >55 or ≥10 mmHg (compared to an awake supine value) to a value exceeding 50 mmHg for ≥10 min during sleep, sleep disordered breathing, pulmonary hypertension and chronic right-sided heart failure (cor pulmonale) in advanced disease characterize these patients. OSAHS is

rather common in patients with OHS, affecting about 90% of the patients and about 10–20% of patients with OSAHS are suffering from OHS (24,31). The following mechanisms have been involved in the pathogenesis of OHS: obesity leading to abnormal mechanics of the respiratory system, leptin resistance, blunted respiratory response (hypercapnia, hypoxia) and upper airway obstruction leading to sleep disordered breathing (31). In these patients oxygen desaturations are more prevalent than in OSAHS patients. Most of these patients suffer from severe OSAHS so possibly the use of oximetry with end-tidal PCO_2 or transcutaneous PCO_2 even with the use of questionnaires would be interesting for future studies in this setting.

In conclusion, oximetry is a useful tool for patients with severe OSAHS. The predictive values of sleep questionnaires and oximetry were low in mild and moderate OSAHS and the combination between them did not improve their diagnostic values. However it has not been clear yet if asymptomatic patients with mild OSAHS should be treated. On the other hand, symptomatic patients should be treated and when oximetry is negative they should be referred for further investigation with in laboratory PSG.

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None.

Footnote

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

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