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The Erlangen Questionnaire: a new 5-item screening tool for obstructive sleep apnea in a sleep clinic population – A prospective, double blinded study

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Abstract. – OBJECTIVE: The aim of this study was to develop and validate a simplified screening tool for identifying obstructive sleep apnea (OSA) in a sleep clinic population.

PATIENTS AND METHODS: A total of 160 patients from a sleep clinic population was enrolled in the prospective, double-blinded study. OSA was defined by using diagnostic criteria of the ICSD-3 after overnight polysomnography (n=96) or polygraphy (n=64). The first 60 patients filled out a multi-item questionnaire and formed the development group. Subsequently, the five most predictive factors were selected to create the Erlangen Questionnaire (EQ). For validation of the EQ, the next 100 patients formed the validation group.

RESULTS: The following factors were incorporated into the 5-item EQ: (1) ESS > 10, (2) age > 60, (3) gasping and (4) cardiovascular risk factors, (5) witnessed apneas. The EQ had sensitivities of 94.3%, 92.7% and 92.3%, specificities of 50.0%, 33.3% and 22.9%, positive predictive values of 81.5%, 62.9% and 29.6%, and negative predictive values of 78.9%, 78.9% and 89.5% with respect to mild, moderate and severe OSA.

CONCLUSIONS: EQ is a compact 5-item-based, concise and easy-to-use screening tool to identify both male and female patients with OSA in a sleep clinic-population and exhibits all essential factors of internal and external validity. The results of the EQ are comparable to the best-validated and most commonly used STOP-Bang questionnaire regarding sensitivity and specificity in a sleep clinic population.

Key Words:
Obstructive sleep apnea, OSA, Sleep apnoea, Questionnaire, Screening, Validation, STOP-Bang, Sleep clinic population.

Introduction

Obstructive Sleep Apnea (OSA) is the most prevalent form of sleep-disordered breathing in the general population that diminishes quality of life and is associated with many common comorbid conditions (hypertension, coronary artery disease, congestive heart failure, cerebrovascular accidents, cardiac arrhythmias, etc.)[1]. Currently the prevalence of OSA with an Apnea-Hypopnea-Index (AHI) ≥ 15 among 30-70 year-old adults is estimated to be approximately 13% of men and 6% of women[2]. Unfortunately, 82% of men and 93% of women remain undiagnosed, underestimating the prevalence of OSA in the general population[3]. Especially women seem to remain undiagnosed more often and longer than men[4]. Sex differences in the prevalence of OSA have been attributed to some factors, including differences in body fat distribution, craniofacial anatomy/airway mechanics, and lifestyle risk factors, such as alcohol and tobacco use[5]. In addition, women often do not report the classic "high pretest" features of OSA, including witnessed apneas, and instead report symptoms of disrupted sleep, depression, and insomnia[6,7]. Undiagnosed OSA is not only important because of it is medical consequences, but also because of economic consequences due to daytime sleepiness, risk of accidents and lack of productivity[8,9]. An overnight in-laboratory polysomnography (PSG) is considered to be the diagnostic gold standard for diagnosing OSA[10]. This is an expensive, time-consuming diagnostic procedure, requiring highly trained personnel, which does not make it accessible for every patient at a given time or place. This is why a preselection process is required[11]. The goal of this selective process is to generate a high pretest probability, guiding only high-risk patients to a polysomnographic diagnosis. Establishing a required high pretest probability is not easy and there are different clinical concepts[12]. A wide array of screening tools has been developed to this pur-

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pose, but many are not suitable for clinical routine. Different questionnaires that are mostly based on the presence of characteristic symptoms, risk factors and predictors of OSA are most common. Various studies have found different items from and combinations of these questionnaires to be highly predictive of OSA. Even though male sex is additionally seen as an independent risk factor for OSA (OR 3.1), there are differences between genders[6,13,14]. Obesity (OR 1.69 (male); 1.31 (female)) and witnessed apneas (OR 1.81 (male); 1.49 (female)) were described to be of better predictive value for men, while hypertension (OR 1.37 (male); 1.52 (female)) is regarded as being a better predictor for women[6]. Other symptoms that were reported more often by women include insomnia and depression, which did not, however, show any predictive value for OSA[6]. An association with OSA could be demonstrated by Cairns et al[6] for excessive daytime sleepiness measured using the Epworth Sleepiness Scale (ESS; score ≥ 10; OR 1.25 (male); 0.97 (female)), although a clear association between daytime sleepiness and OSA could not be confirmed by several other studies[15,16]. Further potential symptoms of OSA include the following additional symptoms and comorbidities: loud and disruptive snoring (OR 1.69 (male); 1.67 (female)), sudden awakening with choking (OR 1.74 (male); 1.42 (female), witnessed apnea reported by the bed partner (OR 1.81 (male); 1.49 (female)), diabetes (OR 1.12 (male); 1.09 (female)), heart disease (OR 1.34 (male); 1.27 (female)), lack of concentration or memory, psychiatric abnormalities, COPD or asthma, gastro esophageal reflux, accidents associated with sleepiness, nighttime sweating, dry mouth and nocturia[6,11,13]. In addition, Cairns et al [6] found age > 45 years to be a robust predictor for OSA (OR 3.58 (male); 5.06 (female)). This is supported by different studies, which found OSA patients to be significantly older (median age of 56.1 years) compared to healthy subjects, and an increasing prevalence in older patients with a plateau at 60 and 65 years, respectively[4,7]. Further risk factors that are linked to OSA are postmenopausal status (OR 3.5-4.3), neck circumference > 40 cm, hypertrophy of the tonsils, laryngeal- or tracheomalacia, craniofacial abnormalities, hypothyreosis, Cushing-Syndrome, stroke, poliomyelitis, head trauma, Marfan Syndrome and medication with benzodiazepine or other narcotics. While many factors were identified as predictors for OSA, none of them proved to be powerful enough on their own, so there was a need to combine different factors into a predictive model[17]. This knowledge has led to different clinical models and questionnaires, questionnaires proving to be easier to use in the clinical routine. The use of an appropriate screening tool depends on the diagnostic setting, as predictive parameters (sensitivity, specificity, positive predictive values (PPV) and negative predictive values (NPV)) depend on the population in whom it is used (primary care, sleep clinic, surgical population)[18]. In a sleep clinic population the STOP-Bang questionnaire is the best-validated screening device with reliable predictive values. It is easy to assess, consisting of 8 items (snoring, tiredness, observed apnea, blood pressure and BMI, age, neck circumference, gender) and is widely used in different diagnostic settings[19]. Other questionnaires like the Berlin Questionnaire (BQ), Sleep Apnea Scale of the Sleep Disorders Questionnaire (SA-SDQ), Apnea Score (AS) or Haralson's questionnaire are more complex, requiring more items, and are less precise concerning their predictive parameters in a sleep clinic population[18,20-24]. The aim of this prospective double-blinded study was to develop and validate a simplified screening tool for identifying mild, moderate and severe OSA in a sleep clinic population, consisting of an easy-to-administer questionnaire with a maximum of 5 items and without requiring specialized equipment or clinical examination.

Patients and Methods

Patients

The prospective, double-blinded study was conducted in accordance with the amended Declaration of Helsinki and the local Ethics Committee. A thorough literature search on PubMed was performed by the authors and articles were screened for predictive factors for OSA. The most promising predictive factors were filtered and brought up for discussion. A 10-item questionnaire for the development group was agreed upon by consensus. The items with the best performance were chosen to create the "Erlangen Questionnaire" (EQ). Subsequently the EQ was validated in the validation group. Between May 2015 and September 2016, a total of 160 patients were referred to the Sleep Department of the Department of Otorhinolaryngology, Head and Neck Surgery (Friedrich-Alexander University of Erlangen-Nürnberg (FAU)) with suspected sleep disorder and were prospectively enrolled in the study. Exclusion criteria were patients under the

age of 18, pregnant women, patients with significant cognitive impairment or a poorly controlled psychiatric disorder, patients with pre-diagnosed OSA and patients with an incompletely filled out questionnaire. The sleep population in this clinic is diverse and patients present various sleep disorders. The enrolled 160 patients complained about symptoms of snoring or excessive daytime sleepiness and / or unrefreshing sleep and were asked to undergo further diagnostics.

Development Group

The first 60 patients recruited formed the development group and had to complete a 10-item questionnaire. Excessive daytime sleepiness (Item 1) was measured using the Epworth Sleepiness Scale (ESS). ESS was scored in the established way, with a score > 10 being considered suspicious[25]. Besides age (Item 2), waking up with shortness of breath or choking (Item 3), pre-existing cardiovascular diseases (e.g. congestive heart failure, coronary artery disease, myocardial infarction, atrial fibrillation, stroke) or difficulty in adjusting high blood pressure (Item 4) and witnessed apnea by the bed partner (Item 5), history of snoring in supine position (Item 6), consumption of alcohol before sleep (Item 7), suffering from a chronic lung disease (e.g. asthma, COPD) (Item 8) and regular intake of medication for depression or other psychopharmaceuticals (Item 9) had to be answered in a dichotomous/forced-choice (yes/no) manner and were considered suspicious in the case of "yes". The degree of obesity (Item 10) was determined using the BMI (kg/m^2). The complete EQ was phrased in German.

Validation Group

The odds ratio (OR) was used to quantify how strongly the presence of each item (Item 1-10) in the development group was associated with OSA in this sleep clinic population. The most predictive factors were selected to create the EQ. For validation of the EQ, the next 100 patients formed the validation group. All patients of the validation group completed the EQ and were blinded to the results of the questionnaire. All items were self-reported by the patients. Each item was scored individually. The questionnaire overall was scored positive (suspicious of OSA) if at least one item was scored as being suspicious. Subsequently, the patient was referred to polygraphy or polysomnography. The scoring of the questionnaire was performed by a physician experienced in sleep medicine who was blinded to the results of the polysomnography/polygraphy.

Cardiorespiratory polygraphy (PG) and Polysomnography (PSG)

Cardiorespiratory polygraphy (unattended portable monitoring, Type III) was performed as an out-of-center-sleep-test (OCST) using the SOMNOscreen diagnostic system (SOMNOmedics, Randersacker, Germany). The use and technical implementation followed the recommendations of the American Academy of Sleep Medicine (AASM) using standardized procedures including a nasal respiratory flow sensor (nasal pressure cannula), thoracic and abdominal respiratory effort sensors (induction plethysmography), position sensors, pulse oximetry and a snoring microphone[26,27]. The results were analyzed and scored manually according to the AASM criteria (version 2.0, 2012) by a sleep specialist accredited by the German Society of Sleep Medicine (DGSM)[28]. The sleep specialist was blinded to the results of the questionnaire. Cardiorespiratory polysomnography (PSG) was performed in the Sleep Laboratory of the Department of Otorhinolaryngology, Head and Neck Surgery (Friedrich-Alexander University of Erlangen-Nürnberg (FAU)) with the SOMNOscreen diagnostic system (SOMNOmedics, Randersacker, Germany). The technical implementation of the PSG followed the recommendations of the American Academy of Sleep Medicine (AASM) using standardized procedures including an electroencephalogram (EEG; F_4-M_1, C_4-M_1, O_2-M_1), right and left electrooculograms (EOG), electromyograms (EMG) of the mentalis and tibialis muscles, a nasal respiratory flow sensor (nasal pressure cannula), thoracic and abdominal respiratory effort sensors (induction plethysmography), position sensors, pulse oximetry, snoring microphone, a one-lead ECG, and an infrared video recording[27]. The results were analyzed and scored manually according to the AASM criteria (version 2.0, 2012) by a sleep specialist accredited by the German Society of Sleep Medicine (DGSM)[28]. The sleep specialist was blinded to the results of the questionnaire. OSA was defined by using diagnostic criteria (A and B or C) of the ICSD-3[29].

Statistical Analysis

Data were analyzed by a Matlab program (Matlab 2013b, MathWorks, Natick, MA, USA) calculating the mean odds ratios, sensitivity and specificity, PPV and NPV with the respective 95%

confidence intervals (CI) of the EQ used. X^2-tests were used for the analysis of significance of the effects. Cronbach's alpha coefficient was calculated and used to measure the internal consistency of the EQ. Additionally, mean and standard deviations were calculated for several parameters of the patients investigated.

Results

Development Group

A total of 60 patients (49 men, 11 women) with a mean age of 48.8 years (± 12.5 SD), a mean AHI 18.8 (± 17.0 SD) and a mean BMI (kg/m^2) 28.8 (± 5.7 SD) were recruited for the development group. Four variables were significantly predictive for OSA. (Item 1) ESS > 10 (OR 1.77); (Item 2) age > 60 years (OR 5.50); (Item 4) suffering from cardiovascular diseases or difficulty in adjusting high blood pressure (OR 4.0); (Item 5) witnessed apnea by the bed partner (OR 3.14). The variable (Item 3) waking up with shortness of breath or choking (OR 0.43), contrary to our expectations, experiences and the literature (OR > 2), showed only an extremely weak association with OSA and was therefore included by consensus of the authors[30]. The variables Items 1, 2, 3, 4 and 5 were used to form a 5-item screening tool called EQ. The remaining variables Item 6 (history of snoring in supine position), Item 7 (consumption of alcohol before sleep), Item 8 (suffering from a chronic lung disease (e.g. asthma, COPD)), Item 9 (regular intake of medication for depression or other psychopharmaceuticals) and Item 10 (BMI > 35 kg/m^2) showed a weak association with OSA (OR 0.8, 1.1, 0.4, 0.8, 1.2) and were, therefore, excluded from the final questionnaire. The association of Items 1-10 with OSA in the development group is shown in Table IA. 47 out of 60 patients (78.3%) were scored as being "suspicious for OSA" with the EQ. For OSA confirmation diagnostics a total of 19 polygraphies and 41 polysomnographies were performed. On the basis of ICSD-3 criteria, 42 out of 60 patients were diagnosed with OSA, making up a prevalence of 70% for OSA in the development group. The predictive parameters of the EQ in mild, moderate and severe OSA in the development group are shown in Table IB. Baseline characteristics of the development group are shown in Table II.

Validation Group

A total of 100 patients (76 men, 24 women) with a mean age of 48.1 years (± 14.2 SD), a mean AHI 22.5 (± 20.9 SD) and a mean BMI (kg/m^2) 29.3 (± 6.0 SD) were recruited for the validation group. 79 out of 100 patients (79.0 %) were scored as being "suspicious for OSA" with the EQ. For OSA confirmation diagnostics a total of 45 polygraphies and 55 polysomnographies were performed. On the basis of ICSD-3 criteria 70 out of 100 patients were diagnosed with OSA, making up a prevalence of 70% for OSA in the validation group.

58 out of 76 men (76.3%) and 12 out of 24 women (50.0%) were tested positive for OSA. 58 out of 70 (82.9 %) patients with OSA were men and 12 out of 70 (17.1%) were women. The mean age in the OSA population was 50.6 years (± 12.9 SD). The mean AHI in the OSA population was 30.4 (± 20.4 SD) and the mean ESS score was 8.9 (± 4.4 SD). 18 out of 76 men (23.7%) and 12 out of 24 women (50.0%) were tested negative for OSA. The mean age of the non-OSA population was 42.3 years (± 15.5 SD). The mean AHI was 4.4/h (± 3.4 SD). The mean ESS score was 6.9 (± 4.2 SD). Baseline characteristics are shown in Table II.

Table IA. Association of the different items with OSA in the development group; OR = odds ratio; 95% CI = 95% Confidence Interval; n=60.

Development group	Total Item "yes" (%)	OSA Item "yes" (%)	Non-OSA Item "yes" (%)	OR	*p*	95% CI
Item 1	23.3	78.6	21.4	1.77	0.43	0.43-7.32
Item 2	20.0	91.7	8.3	5.50	0.10	0.72-50.8
Item 3	28.3	58.8	41.2	0.43	0.17	0.13-1.43
Item 4	15.0	88.9	11.1	4.00	0.16	0.54-39.69
Item 5	58.3	80.0	20.0	3.14	0.07	0.91-8.83
Item 6	20.0	66.6	33.3	0.82	0.78	0.21-3.18
Item 7	25.0	73.3	26.7	1.1	0.75	0.34-4.59
Item 8	3.3	50.0	50.0	0.4	0.50	0.02-6.46
Item 9	10.0	66.7	33.3	0.8	0.85	0.14-5.07
Item 10	10.0	83.3	16.7	1.2	0.46	0.25-21.20

Table IB. Predictive parameters of the "Erlangen Questionnaire" in mild, moderate and severe OSA in the development group; n=60. *According to diagnostic criteria A and B (ICSD-3) 29, **AHI ≥ 15, ***AHI≥30.

Development group	Mild OSA*	Moderate OSA**	Severe OSA***
Sensitivity in % (95% CI)	90.5 (76.5-96.9)	86.6 (68.4-95.6)	92.3 (62.1-99.6)
Specificity in % (95% CI)	50.0 (26.8-73.2)	30.0 (15.4-49.6)	25.5 (14.4-40.6)
PPV in % (95% CI)	80.9 (66.3-90.4)	55.3 (40.2-69.5)	25.5 (14.4-40.6)
NPV in % (95% CI)	69.2 (38.9-89.6)	69.2 (38.9-89.6)	92.3 (62.1-99.6)
Prevalence in %	70.0	50.0	21.7

Table II. Baseline characteristics of the development group and validation group.

	Development group			Validation group		
	Total	OSA	Non-OSA	Total	OSA	Non-OSA
AHI (/h) (±SD)	**18.8** (± 17.0)	**24.8** (± 17.3)	**4.6** (± 3.7)	**22.5** (± 20.9)	**30.4** (± 20.4)	**4.4** (± 3.4)
Age (years) (±SD)	**48.8** (± 12.5)	**51.6** (± 12.1)	**42.4** (± 10.9)	**48.1** (± 14.2)	**50.6** (± 12.9)	**42.3** (± 15.5)
BMI (kg/m^2) (±SD)	**28.8** (± 5.7)	**29.4** (± 5.9)	**27.2** (± 4.7)	**29.3** (± 6.0)	**30.7** (± 5.9)	**26.2** (± 4.9)
Gender (m:f)	**4.5:1**	**4.25:1**	**5:1**	**3.2:1**	**4.8:1**	**1.5:1**
Prevalence (%)	**70**	-	-	**70**	-	-

Table III. Predictive parameters of the "Erlangen Questionnaire" in mild, moderate and severe OSA in the validation group; n=100. *According to diagnostic criteria A and B (ICSD-3)29, **AHI ≥ 15, ***AHI≥ 30.

Validation group	Mild OSA*	Moderate OSA**	Severe OSA***
Sensitivity in % (95% CI)	94.3 (85.3-98.2)	92.7 (81.6-97.6)	92.3 (73.4-98.6)
Specificity in % (95% CI)	50.0 (31.7-68.3)	33.3 (20.4-49.1)	22.9 (14.3-34.5)
PPV in % (95% CI)	81.5 (70.9-88.9)	62.9 (51.5-73.2)	29.6 (20.3-40.9)
NPV in % (95% CI)	78.9 (53.9-93.0)	78.9 (53.9-93.0)	89.5 (65.5-98.2)
Prevalence in %	70.0	55.5	26.0

Mild OSA

Defining OSA according to ICSD-3 criteria A and B, the Erlangen Questionnaire scored 66 patients as being true positive and 15 as true negative. 15 patients were false positive, while 4 were scored false negative. This gives a sensitivity of 94.3%, a specificity of 50.0%, a PPV of 81.5% and a NPV of 78.9% (Table III).

Moderate OSA (AHI ≥ 15)

55 out of 100 patients presented with AHI ≥ 15. With respect to moderate OSA, 51 patients were tested true positive and 15 true negative, while 30 patients were scored false positive and 4 patients false negative. This leads to a sensitivity of 92.7%, a specificity of 33.3%, a PPV of 62.9% and a NPV of 78.9% (Table III).

Severe OSA (AHI ≥ 30)

26 out of 100 patients presented with AHI ≥ 30. With respect to severe OSA, 24 patients were tested true positive and 17 true negative, while 57 were tested false positive and 2 false negative. Overall this leads to a sensitivity of 92.3%, a specificity of 22.9%, a PPV of 29.6% and NPV of 89.5% (Table III).

Retest Reliability

To check the test-retest correlation, 15 patients answered the EQ twice. The mean time interval was 63.6 days (range 2-365 days). 13 out of 15 patients (86.7%) were found to have the same test results. The overall Cronbach's alpha was 0.70, thus showing an acceptable reliability.

Table IV. Overview: predictive parameters of the OSA-screening questionnaires in a sleep clinic population: For STOP-Bang, AS, BQ, Haraldsson and SA-SDB based on *AHI / **AI / ***RDI ≥ 5, whereas EQ based on diagnostic criteria of ICSD-3[29].

	Prevalence (%)	Sensitivity	Specificity	PPV	NPV
EQ	70	94	50	82	79
STOP-Bang[19*]	85	90	49	91	46
AS[18*]	51	59	69	66	62
BQ[18***]	43	68	46	48	65
Haraldsson[18**]	76	81	80	92	57
SA-SDQ[18*]	55	80	66	74	72

Discussion

The 5-item EQ seems to be an effective screening tool for OSA in a sleep clinic population where a high sensitivity is essential. We found our sensitivity to be slightly better compared to the most common questionnaires (STOP-Bang, BQ, SA-SDQ, AS and Haraldsson) validated in sleep populations (Table IV)[18,25]. The STOP-Bang questionnaire, being the most commonly used screening tool and described as the questionnaire with the highest methodical validity, is comparable with regards to sensitivity (90% *vs.* 94%) and specificity (49% *vs.* 50%)[19]. However, the STOP-Bang questionnaire appears to have a relatively poor specificity (18.0%), but an acceptable sensitivity (83.8%), especially in identifying younger and non-obese (military) patients as at high risk of AHI > 5[31]. Compared with the Haraldsson questionnaire and the SA-SDQ, the EQ shows a better performance due to the higher sensitivity (94% *vs.* 81% *vs.* 80%), even if the specificity is lower (50% *vs.* 80% *vs.* 66%). These results must take account of the fact that in the Haraldsson questionnaire an OSA definition (apnea index > 5) deviating from the EQ (ICSD-3) was examined in addition to a smaller (n=42) study population, which was limited to habitual snorers[18]. For this reason a direct comparability of the test quality criteria of the two questionnaires appears difficult in this context (Table IV). Alternatively to screening questionnaires, there are morphometric models for predicting OSA. Kushida et al[32] used BMI, neck circumference, palatal height, distance from the dorsum of the tongue to the highest point of the palate, maxilla-intermolar distance and overjet to reach a remarkable sensitivity of 97.6%, a specificity of 100%, PPV of 100% and NPV of 88.5%. Tsai et al[30] developed a decision rule using a three-variable model (cricomental space <1.5 cm, pharyngeal grade > II, overjet), which reached a sensitivity of 33%, specificity of 100%, PPV of 100% and NPV of 25%. Even though the results seem to impress, the morphometric models are too complex and have, therefore, not yet been implemented in a clinical routine setup. While other validated questionnaires were developed mainly for a primary care setting (e.g. BQ) or preoperative setting (STOP-Bang), the EQ was developed for use in a sleep clinic population[11,16,27,33]. This is important, as a fundamental challenge for any screening device is the influence of prevalence on the predictive value. A population with low prevalence tends to produce more false positive results than a population with a high prevalence, which produces a higher rate of false negative results. In a sleep clinic population the prevalence of OSA is on the high side, causing a possibly high rate of false negative results and affecting the NPV, leaving patients with a negative test result still with a high risk of OSA[12,28]. As described by Bianchi et al[34], with a rising prevalence (for example 30-50%), only the most powerful tests provide NPV of more than 90% to 95%. Even though the EQ does not provide such high NPV, it still outperforms other validated questionnaires in this category. As Bianchi et al[34] also suggested, an acceptable value for residual risk of OSA should be reached by consensus (for example NPV of 75%), which we exceeded in our results, but the acceptable residual risk also depends on the personal circumstances of a patient. The residual risk of OSA (of e.g. 10%) after a negative screen might be acceptable for an asymptomatic adult, but is unacceptable for a professional driver[34]. So, overall, not only is the estimation of pretest probability an important pitfall in interpreting diagnostic tests, but negative test results in a high prevalence population are also of importance, as well as how to deal with them. The main clinical pitfall in screening high-risk populations is that a screening test alone may not have sufficient discriminative power for a negative result to effectively lower disease probability below an acceptable OSA risk threshold, as Bianchi et al[34] state. None of the existing validated questionnaires

used in a sleep population provide the described acceptable threshold, whereas the EQ can reduce the residual risk of OSA at least to about 20% with NPV of 79%. Moreover, the EQ exhibits all the factors Abrishami et al[18] described as essential for the validity of a questionnaire with factors of internal validity (valid reference standard, definition of OSA based on a reference standard, blinded study, independent interpretation of the reference standard and prospective study) and of external validity (inclusion and exclusion criteria, information on study setting, demographics, explicit cut-off value for reference standard and selection of patients for reference testing) being in place. As described by Chai-Coetzer et al[35], a good screening tool should consist of a maximum of five items and not require special equipment or examinations. The EQ also fulfills these criteria, consisting of five items that are routinely obtainable in a clinical setup for a sleep clinic population. For the EQ, this ensures the characteristics imposed by Abrishami et al[18] on a good screening tool, i.e. feasibility, accuracy, and generalizability. However, there are also some limitations to our study. In contrast to most studies with a similar setting, not all diagnoses of OSA were ensured with PSG as the diagnostic gold standard, but also with unattended PG (Type III, OCST). This allows for potential misdiagnosis, as the PG tends to underestimate the severity of AHI and can lead to up to 17% 'false negative' results[26]. Using PSG alone for confirmation of OSA would probably lead to a slight shift in hard-to-classify patients on the borderline of severity limits between healthy to mild or mild to moderate or moderate to severe OSA, which might lead to an increased specificity and a decreased sensitivity. As with most studies evaluating OSA questionnaires, the choice of diagnostic cut-off values for AHI/AI/RDI significantly influences the prevalence and predictive parameters and has a great impact on the study results[30]. Mainly cut-off values of AHI / AI / RDI > 5 or RDI > 10 were used to confirm OSA[18]. The diagnosis OSA is, however, not only defined by the isolated consideration of the poly(somno)graphically detected respiratory events (AHI / RDI / AI), but also by taking additional complaints, symptoms and pre-existing conditions into consideration. For this reason, in our study we strictly adhered to the diagnostic criteria of the ICSD-3, which is the standard manual for the definition of OSA[29]. This fact clearly distinguishes us from other studies, since we were not looking for an isolated cut-off value of respiratory events, but for the disease OSA itself. To our knowledge this is the first study of this kind. Even with regards to the different gender-specific complaints and risk factors for OSA, the EQ offers solid predictive parameters for men as well as for women (Table V), a fact that was rarely taken into account in former studies.

Conclusions

The EQ is a compact 5-item-based, concise and easy-to-use screening tool to identify both male and female patients with OSA in a sleep-clinic-population and exhibits all essential factors of internal and external validity. Although the results of the EQ are comparable to the best validated and most commonly used STOP-Bang questionnaire regarding sensitivity and specificity in a sleep clinic population, the EQ still needs to be validated in surgical and primary care populations.

Table V. Predictive parameters of the "Erlangen Questionnaire" in mild, moderate and severe OSA in the validation group separated by gender. *According to diagnostic criteria A and B (ICSD-3) 29, **AHI ≥ 15, ***AHI ≥ 30.

	Mild OSA*		Moderate OSA**		Severe OSA***	
Validation group	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
Sensitivity in % (95% CI)	**96.5** (87.0-99.4)	**83.3** (31.1-72.6)	**95.8** (84.6-99.3)	**71.4** (30.3-94.9)	**91.3** (70.5-98.5)	**100.0** (30.9-100.0)
Specificity in % (95% CI)	**52.6** (29.5-74.8)	**45.5** (18.1-75.4)	**32.1** (16.6-52.4)	**35.3** (15.3-61.4)	**16.9** (8.5-30.3)	**38.1** (18.9-61.3)
PPV in % (95% CI)	**86.2** (74.8-93.1)	**62.5** (35.9-83.7)	**70.8** (58.0-81.1)	**31.3** (12.1-58.5)	**32.3** (21.5-45.2)	**18.8** (4.9-46.3)
NPV in % (95% CI)	**83.3** (50.9-97.1)	**71.4** (30.3-94.9)	**81.8** (47.8-96.8)	**75.0** (35.6-95.5)	**81.8** (47.8-96.8)	**100.0** (59.8-100.0)
Prevalence in %	**76.3**	**50.0**	**63.2**	**29.2**	**30.3**	**12.5**

Conflict of interest

The authors declare no conflicts of interest.

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