Sleep Medicine 57 (2019) 15–20

Contents lists available at ScienceDirect

Sleep Medicine

journal homepage: www.elsevier.com/locate/sleep

Original Article

The STOP-Bang and Berlin questionnaires to identify obstructive sleep apnoea in Alzheimer's disease patients

Carme Jorge [a], Ivan Benítez [b, c], Gerard Torres [b, c], Faride Dakterzada [a], Olga Minguez [b], Raquel Huerto [a], Montse Pujol [b], Anna Carnes [a], Anna Michela Gaeta [b], Mireia Dalmases [b, c], Aurora Gibert [a], Manuel Sanchez de la Torres [b, c], Ferran Barbé [b, c], Gerard Piñol-Ripoll [a, *]

[a] Unitat Trastorns Cognitius, Clinical Neuroscience Research, IRBLleida-Hospital Universitari Santa Maria, Lleida, Spain
[b] Group of Translational Research in Respiratory Medicine, Hospital Universitari Arnau de Vilanova and Santa Maria, IRBLleida, Lleida, Spain
[c] Centro de Investigación Biomédica en Red de Enfermedades Respiratorias (CIBERES), Madrid, Spain

ARTICLE INFO

Article history:
Received 13 July 2018
Received in revised form
18 January 2019
Accepted 22 January 2019
Available online 8 February 2019

Keywords:
Alzheimer's disease
Obstructive sleep apnoea
Screening tool
Berlin questionnaire
STOP-Bang questionnaire

ABSTRACT

Background: A close relationship between obstructive sleep apnoea (OSA) and Alzheimer's disease (AD) has been described in recent years. OSA is a risk factor for AD, but the diagnosis and clinical characteristics of OSA in patients with AD is not well understood. This study evaluated the clinical utility of two screening questionnaires, the STOP-Bang questionnaire (SBQ) and the Berlin questionnaire (BQ), to identify which patients with mild AD are at higher risk of having OSA and to determine the clinical predictors of OSA in this population.

Methods: In this study, 91 consecutive outpatients with mild AD were prospectively evaluated with the SBQ and the BQ. All patients underwent level 1 in-laboratory polysomnography. The predictive performance of the questionnaires were calculated for different apnoea-hypopnoea index (AHI) cut-offs.

Results: The median age of the patients was 76.0 (73.0; 80.0) years, and 58 (63.7%) were female. Of those, 81 patients (89.02%) were found to have OSA defined by an AHI > 5 events/h. Comparing the predictive performances of the SBQ and the BQ, the SBQ was found to have a higher diagnostic sensitivity (85% vs 4%), a lower specificity (35% vs. 96%), a higher positive predictive value (PPV) (44% vs 33%) and negative predictive value (NPV) (80% vs 65%) for detecting severe OSA at an AHI cut-off of 30 events/h. None of the items alone in the two questionnaires predicted the risk of OSA. A modified version of the SBQ, with new cut-off points for several variables according to the characteristics of AD patients, showed a slightly greater AUC than the standard SBQ (AUC 0.61 vs 0.72).

Conclusion: There is a high prevalence of OSA among patients with mild AD. The SBQ and the BQ are not good screening tools for detecting OSA in patients with AD. A modified version of SBQ could increase the detection of these patients.

1. Introduction

Obstructive sleep apnoea (OSA) is characterized by an intermittent and repetitive partial (hypopnoea) or total (apnoea) occlusion of the upper airway. Clinically, OSA manifests with excessive daytime sleepiness and metabolic, respiratory, cardiac and cognitive-behavioural disorders [1–3]. OSA is considered a cardiovascular risk factor and has been shown to worsen cognitive performance, especially executive function, in healthy subjects [4].

OSA has been recently shown in population studies to increase the risk of developing Alzheimer's disease (AD) [5,6]. The presence of OSA has also been shown to advance the diagnosis of both mild cognitive impairment (MCI) and AD, suggesting that it could accelerate the progression of these diseases in early stages [7]. In particular, OSA promotes the deposition of amyloid β in the brain, which is considered the key hallmark in the pathophysiology of AD [8].

Although OSA and AD both have high prevalence in the population over 65 years of age, few studies have evaluated the actual

* Corresponding author. Cogntive Disorders Unit, Hospital Santa Universitari Maria, Rovira Roure nº 44, 25198, Lleida, Spain. Fax: +34 976 727366.
E-mail address: gerard_437302@hotmail.com (G. Piñol-Ripoll).

https://doi.org/10.1016/j.sleep.2019.01.033
1389-9457/

prevalence of OSA in the AD population, as the diagnosis of OSA is generally under-emphasized in this group of patients [9,10].

The current gold standard technique for the diagnosis of OSA is polysomnography (PSG). Yet, its high cost and low availability and the fact that patients with cognitive impairment particularly have difficulty sleeping outside their usual environment hinder the use of PSG.

Due to these limitations, simple screening questionnaires, including the STOP-Bang questionnaire (SBQ) [11] and the Berlin questionnaire (BQ) [12], have been used to identify people at high risk of OSA. The usefulness of these tests has been validated in primary care settings and in different sub-populations, such as in diabetic subjects [13], pre-surgical subjects [14] and stroke patients [15]. However, there are limited data regarding the use of these tests in patients with cognitive impairment or dementia.

The purpose of this study was to (i) assess the prevalence of OSA in mild AD; (ii) evaluate the clinical utility of the SBQ and the BQ to identify which patients with AD are at higher risk of having OSA; and (iii) determine clinical predictors of OSA in this population.

2. Methods

We prospectively recruited 91 subjects from a sample of outpatients who visited the Cognitive Disorders Unit at Hospital Universitari Santa Maria in Lleida between April 2015 and August 2017. These subjects were included in the NCT02814045 study which is a large cohort of patients and whose main objective was to compare the cognitive progression of patients with Alzheimer's disease with and without OSA after one year of follow up. Therefore, these results are a secondary post-hoc analysis of a more extensive cohort.

All patients were acetylcholinesterase inhibitor drug-naïve patients recently diagnosed with mild to moderate AD (Mini-Mental State Examination (MMSE) score $\geq$ 20). AD was diagnosed according to the clinical criteria of NIA-AA [16].

Exclusion criteria were as follows: (1) patients with cognitive impairment caused by other conditions, (2) the presence of lesions identified on computed tomography (CT) or brain magnetic resonance imaging (MRI) such as stroke, brain tumour, cortical dysplasia giving rise to epilepsy, etc. or analytical alterations (ionic alterations, hypothyroidism, deficit of cobalamin or folic acid, positive syphilitic serology) that could justify the presence of cognitive impairment; (3) patients with AD and an MMSE score < 20 (patients with moderate to severe or severe cognitive impairment); and (4) patients who slept less than 180 min in the sleep study.

We performed supervised PSG according to international guidelines [17]. PSG consisted of electroencephalography (F3, F4, C3, C4, O1, and O2, referred to the bilateral ears); right and left electro-oculography, surface electromyography (EMG) of the mentalis muscle; surface EMG of the right and left flexor digitorum superficialis in the upper limbs; surface EMG of the right and left anterior tibialis in the lower limbs; electrocardiography; nasal and oral airflow assessment; nasal pressure cannula; thoracic and abdominal movement assessment; and oxyhaemoglobin saturation measurement.

Apnoea was defined by the absence of airflow for more than 10 s. Hypopnoea was defined as any airflow reduction that lasted more than 10 s and resulted in arousal or oxygen desaturation. We considered desaturation a decrease in SaO2 greater than 3%. The apnoea-hypopnoea index (AHI) was defined as the sum of the number of apnoea plus hypopnoea events per hour of sleep.

All participants underwent cognitive assessment using the MMSE [18] and received a semi-structured sleep questionnaire that included the SQB and the BQ for the detection of OSA.

The SBQ comprises eight items requiring dichotomous responses related to OSA, snoring, tiredness, observed sleep apnoea, high blood pressure, body mass index (BMI), age, neck circumference and gender [11]. The score ranges from 0 to 8, and the highest scores have been associated with a high probability of OSA. The cut-off score of $\geq$3 is considered high risk of moderate/severe OSA and <3 is considered low risk [19].

The BQ consists of three items related to the risk of having OSA. The first is snoring and is analysed through five questions (presence, intensity and frequency of snoring, if it disturbs other people and cessation of breathing during sleep); a score equal to or greater than two points is considered a positive outcome for this category. The second item is fatigue, which is evaluated by three questions (frequency of asthenia when getting up and during the day and feeling drowsy or falling asleep while driving); a score equal to or greater than two is considered a positive outcome for this category. The third is the presence of hypertension or a BMI >30. Depending on the individual responses and the total score of the items, patients can be classified as high risk or low risk OSA [12].

General medical aspects such as age, sex, schooling, smoking, drinking, family history of AD, personal pathological antecedents such as hypertension, diabetes mellitus, hypercholesterolemia, stroke, depression, psychiatric history and psycho-drug consumption were also evaluated in the whole sample.

The statistical analyses and data processing procedures were performed using R software, version 3.4.2 (Vienna, Austria). Quantitative variables were described as the mean and standard deviation (SD) or the median and interquartile range (IQR) (the numbers in some of the brackets are the 25th and 75th percentiles) according to the normality of the data. Absolute and relative frequencies were used to describe qualitative variables. The AHI was dichotomized by cut-off points of 5, 15 and 30 events/hour. Receiver operating characteristic (ROC) curve analyses were performed, and the best cut-off point for risk classification by the questionnaire was determined. The area under the curve (AUC), sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) of the questionnaires were calculated against AHI.

The optimal cut-off points for age, BMI and neck circumference to discriminate severe OSA were evaluated. The cut-off was defined as the threshold that maximizes the distance to the identity (diagonal) line:

2.1. *Max (sensitivities + specificities)*

The optimal cut-off point was included in a new version of the SBQ specifically designed for the AD population, and AUC, sensitivity, and specificity were evaluated. In addition, a multiple correspondence analysis of the parameters of the new version of the SBQ was performed with several AHIs as a supplementary variable.

This study was conducted in accordance with the Declaration of Helsinki and approved by the care ethics committee (CE-1218). All patients signed informed consent.

3. Results

We collected a consecutive series of 91 subjects with a recent diagnosis of mild-moderate AD. A flowchart is shown in the supplementary data (eFig. 1). These subjects had a median (IQR) age of 76.0 [73.0–80.0] years, and 63.7% were women. Arterial hypertension was the most frequent vascular risk factor (57.1%), followed by dyslipidemia (40.7%) and diabetes (22%). According to daytime sleepiness, the median Epworth Sleepiness score (ESS) was 5.00 (3.00; 8.50), and the mean AHI was 20.7 (10.6; 40.3). All the characteristics of the sample are shown in Table 1.

Table 1
Characteristics of Alzheimer's disease patients according the STOP-Bang questionnaire and the Berlin questionnaire. COPD: Chronic obstructive pulmonary disease; DM: Diabetes mellitus. STOP-BANG low risk is score <3. STOP-BANG high risk ≥3. Berlin Questionnaire low risk <2. Berlin Questionnaire high risk ≥2.

	Total n = 91	STOP-Bang Questionnaire		Berlin Questionnarie	
		Low Risk n = 25	High Risk n = 66	Low Risk n = 77	High Risk n = 3
Physiological characteristics					
Gender, *Female*	58 (63.7%)	25 (100%)	33 (50.0%)	49 (63.6%)	1 (33.3%)
Age, *years*	76.0 [73.0; 80.0]	73.0 [72.0; 80.0]	77.5 [73.0; 80.0]	76.0 [73.0; 80.0]	73.0 [73.0; 73.0]
BMI, kg/m^2	27.6 [25.1; 30.2]	25.9 [24.1; 29.4]	27.8 [25.7; 30.2]	27.4 [24.7; 29.6]	30.4 [27.8; 31.9]
Neck circumference, *cm*	35.5 [34.0; 38.0]	34.0 [33.0; 35.0]	37.0 [35.0; 40.0]	35.0 [34.0; 38.0]	44.0 [40.0; 44.5]
Lifestyle habits					
Tobacco use					
Non-smoker	73 (80.2%)	24 (96.0%)	49 (74.2%)	63 (81.8%)	1 (33.3%)
Smoker	2 (2.20%)	0 (0.00%)	2 (3.03%)	2 (2.60%)	0 (0.00%)
Ex-smoker	16 (17.6%)	1 (4.00%)	15 (22.7%)	12 (15.6%)	2 (66.7%)
Alcohol, *yes*	22 (24.2%)	4 (16.0%)	18 (27.3%)	20 (26.0%)	2 (66.7%)
Physical activity					
Low	56 (61.5%)	15 (60.0%)	41 (62.1%)	48 (62.3%)	3 (100%)
Moderate	15 (16.5%)	5 (20.0%)	10 (15.2%)	13 (16.9%)	0 (0.00%)
Vigorous	20 (22.0%)	5 (20.0%)	15 (22.7%)	16 (20.8%)	0 (0.00%)
Comorbidity					
Depression	30 (33.0%)	10 (40.0%)	20 (30.3%)	25 (32.5%)	1 (33.3%)
Anxiety	13 (14.3%)	2 (8.00%)	11 (16.7%)	11 (14.3%)	1 (33.3%)
Arterial hypertension	52 (57.1%)	5 (20.0%)	47 (71.2%)	43 (55.8%)	2 (66.7%)
Cardiopathy	15 (16.5%)	2 (8.00%)	13 (19.7%)	13 (16.9%)	1 (33.3%)
Stroke	5 (5.49%)	0 (0.00%)	5 (7.58%)	5 (6.49%)	0 (0.00%)
COPD	7 (7.69%)	1 (4.00%)	6 (9.09%)	6 (7.79%)	1 (33.3%)
Asthma	1 (1.10%)	1 (4.00%)	0 (0.00%)	77 (100%)	3 (100%)
DM	20 (22.0%)	3 (12.0%)	17 (25.8%)	17 (22.1%)	1 (33.3%)
Dyslipidemia	37 (40.7%)	9 (36.0%)	28 (42.4%)	30 (39.0%)	0 (0.00%)
Hypercholesterolemia	34 (37.4%)	9 (36.0%)	25 (37.9%)	27 (35.1%)	0 (0.00%)
Epworth Sleepiness Scale	5.00 [3.00; 8.50]	4.00 [2.00; 7.00]	6.00 [3.00; 9.00]	5.00 [3.00; 8.00]	5.00 [4.00; 7.00]
PSG parameters					
Total sleep time, *min*	413 (40.4)	419 (39.3)	410 (40.8)	413 (41.0)	399 (14.0)
Respiratory arousal index, *events/h*	39.7 [23.8; 51.0]	30.2 [25.0; 43.2]	42.5 [23.4; 55.6]	39.6 [25.0; 51.1]	29.0 [23.9; 40.1]
Apnoea-hypopnoea index, *events/h*	20.7 [10.6; 40.3]	16.0 [6.81; 26.6]	24.3 [12.0; 45.1]	20.2 [10.5; 35.3]	25.4 [15.2; 32.5]
Time with SaO2 < 90, *%*	2.09 [0.20; 9.18]	1.58 [0.16; 7.00]	2.44 [0.20; 9.71]	1.90 [0.30; 9.36]	0.07 [0.04; 27.7]

The PSG test diagnosed 81 patients (89.02%) with OSA (AHI > 5); 34 (37.36%) subjects had severe OSA with AHI > 30, 23 (25.27%) had moderate OSA with 15 < AHI ≤ 30, and 24 (26.37%) had mild OSA with 5 < AHI ≤ 15 (see Table 1). The remaining 10 (10.98%) patients had a negative diagnosis of OSA (AHI ≤ 5).

The median [IQR] SBQ score was 3 (2–4). The questionnaire classified 66 subjects (72.52%) as high risk for severe OSA (cut-off ≥ 3 points). The SBQ corresponded to a high sensitivity (85%), a low specificity (35%) and AUC was 0.61.

The median [IQR] BQ score was 0 [0–1] and only classified three subjects (3.75%) as high risk for severe OSA (cut-off was score ≥ 2 points). The BQ corresponded to a low sensitivity (4%), a high specificity (96%). The AUC was 0.58 with the optimal cut point (≥0) lower than the stipulated points (≥2). The results of the evaluation of the validity of the questionnaires for AHI cut-off points of 5, 15 and 30 events/h are presented in Table 2.

Given that the objective of any screening test should be to identify patients with severe OSA, in whom treatment with continuous positive airway pressure (CPAP) would be recommended, we considered the predictive performance of the SBQ and the BQ at the AHI cut-off point of 30 events/h to be significant. As shown in Table 3, some of individuals categories of SBQ such as tiredness, neck circumference >40 cm and gender (men) were predictors to identify patients with moderate OSA. However, none of the individual categories in the BQ and none of the classical symptoms of OSA alone, such as tiredness, snoring, obesity, observed sleep apnoea, hypertension, male gender or high neck circumference, included in the SBQ were able to significantly identify subjects with severe OSA.

After determining that the BQ is not a useful screening test in this group of patients due to its low sensitivity, we derived the optimal cut-offs for each item on the SBQ questionnaire. We evaluated the age cut-off point, BMI and neck circumference that optimize the discrimination of patients with and without severe OSA (age > 70 years; BMI > 26 kg/m^2; neck circumference >26.5 cm). According to these new cut-off points we evaluated the usefulness of this scale that we call modified SBQ. The modified SBQ showed a sensitivity of 0.61 (95% IC 0.47–0.74), a specificity of 0.76 (95% IC 0.59–0.89), a positive predictive value of 0.81 (95% IC 0.66–0.91) and a negative predictive value of 0.54 (95% IC

Table 2
Predictive parameters for the STOP-Bang and Berlin questionnaires. AHI = apnoea-hypopnoea index; NPV = negative predictive value; PPV = positive predictive value; AUC = area under the ROC curve; ROC = receiver-operating characteristic.

	STOP-Bang Questionnarie	Berlin Questionnarie
AHI >5		
Sensitivity	0.74 (0.63–0.83)	0.03 (0–0.1)
Specificity	0.4 (0.12–0.74)	0.9 (0.55–1)
PPV	0.91 (0.81–0.97)	0.67 (0.09–0.99)
NPV	0.16 (0.05–0.36)	0.12 (0.05–0.21)
AUC	0.6 (0.42–0.79)	0.65 (0.48–0.83)
AHI > 15		
Sensitivity	0.77 (0.64–0.87)	0.04 (0–0.13)
Specificity	0.35 (0.2–0.54)	0.97 (0.82–1)
PPV	0.67 (0.54–0.78)	0.67 (0.09–0.99)
NPV	0.48 (0.28–0.69)	0.36 (0.26–0.48)
AUC	0.6 (0.48–0.72)	0.58 (0.48–0.69)
AHI > 30		
Sensitivity	0.85 (0.69–0.95)	0.04 (0–0.18)
Specificity	0.35 (0.23–0.49)	0.96 (0.87–1)
PPV	0.44 (0.32–0.57)	0.33 (0.01–0.91)
NPV	0.8 (0.59–0.93)	0.65 (0.53–0.75)
AUC	0.61 (0.5–0.73)	0.58 (0.47–0.7)

Table 3
Clinical characteristics in patients with and without moderate and severe OSA.

	Total n = 91	AHI ≤ 30 n = 57	AHI >30 n = 34	p value	AHI <15 n = 34	AHI >15 n = 57	p value
Berlin Questionnarie							
Category 1	15 (18.8%)	8 (15.4%)	7 (25.0%)	0.453	3 (10.3%)	12 (23.5%)	0.248
Category 2	3 (3.75%)	3 (5.77%)	0 (0.00%)	0.548	1 (3.45%)	2 (3.92%)	0.999
Category 3	15 (18.8%)	8 (15.4%)	7 (25.0%)	0.453	5 (17.2%)	10 (19.6%)	0.999
STOP-Bang Questionnarie							
Snore	63 (69.2%)	36 (63.2%)	27 (79.4%)	0.164	19 (55.9%)	44 (77.2%)	0.058
Tired	27 (29.7%)	20 (35.1%)	7 (20.6%)	0.220	15 (44.1%)	12 (21.1%)	0.036
Observed	14 (15.4%)	8 (14.0%)	6 (17.6%)	0.872	4 (11.8%)	10 (17.5%)	0.661
Pressure	52 (57.1%)	31 (54.4%)	21 (61.8%)	0.639	20 (58.8%)	32 (56.1%)	0.975
BMI > 35 kg/m2	3 (3.30%)	1 (1.75%)	2 (5.88%)	0.553	0 (0.00%)	3 (5.26%)	0.290
Age > 50 years	91 (100%)	57 (100%)	34 (100%)		34 (100%)	57 (100%)	
Neck > 40 cm	13 (14.3%)	5 (8.77%)	8 (23.5%)	0.067	1 (2.94%)	12 (21.1%)	0.027
Gender, woman	58 (63.7%)	41 (71.9%)	17 (50.0%)	0.060	27 (79.4%)	31 (54.4%)	0.029

0.39–0.69). Fig. 1 shows the qualifying power of both the original and modified test, with a slightly higher AUC for our proposed test. After re-evaluating the cut-off points, multiple correspondence analysis showed an association of OSA with the components of the new version of the SBQ (eFig. 2).

4. Discussion

In this work, we enrolled 91 AD patients to evaluate baseline demographic and pathological characteristics between OSA and non-OSA patients and to evaluate the predictive performance of two important OSA screening tests, the SBQ and the BQ, at the different cut points used to evaluate the different stages of OSA, such as an AHI of 5 events/h, 15 events/h, and 30 events/h. The results showed that neither the SBQ nor the BQ is a good OSA screening test for a population with such a high prevalence of OSA. To our knowledge, this is the first work to evaluate the predictive values of the SBQ and the BQ for detecting OSA in AD patients.

A growing amount of evidence regarding the relationship between sleep and AD has been described in recent years. Several studies have showed the importance of OSA as a possible risk factor for AD [5,6,20]. However, the true prevalence of OSA in this group of patients is unknown, given that the few existing studies were performed many years ago [10]. As PSG can be difficult to perform in this patient group due to the behavioural alterations that may occur at night, such as insomnia and the possibility that patients become disoriented by PSG, could indicate that a large amount of relevant data is lacking.

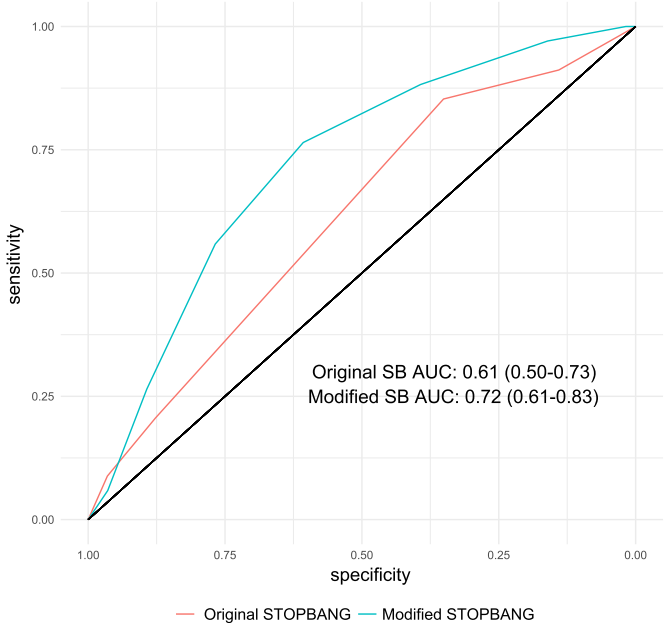

Fig. 1. Shows the qualifying power of both the original and proposed Stop-Bang tests, with a slightly higher AUC for our proposed test.

One way to try to select patients who may truly benefit from PSG is to identify subjects at high risk of presenting sleep disturbances, and more specifically, OSA. Among these options, we identified various screening questionnaires, such as the SBQ and the BQ, that have been used in healthy populations and different population sub-groups.

The SBQ was created as a screening tool for OSA in a healthy population [11]. It is advantageous in that it can be implemented easily and quickly and has been applied in the general population [21], in specific sleep units [22], and in patients with different pathologies such as surgical patients [23], pregnant women [24], patients with kidney failure [25], and patients with mental illness [26].

In our sample, the SBQ showed relatively good sensibility (77% and 85%) and low specificity (35% and 35%) in patients with moderate (AHI 15–30) and severe OSA (AHI >30), respectively. In comparison, these questionnaires showed higher sensitivities of 93% and 100% and specificities of 43% and 37%, in moderate and severe OSA, respectively, in the general population [11]. A systematic meta-analysis showed that in the sleep clinic population, the SBQ had sensitivities of 94% and 96% for detecting moderate and severe OSA, respectively [27].

In patients with other neurological disorders, such as stroke/transient ischemic attack (TIA), the SBQ moderately predicted OSA with a sensitivity of 93.8%. Yet, the neck circumference measure was excluded in the evaluation in this study [15]. The AUC in TIA patients with AHI ≥10 ranged from 0.567 to 0.813 [28–30] in several previous studies and was reported to be 0.71 in surgical patients [19], all higher than the AUC of 0.605 for AHI > 15 events/h and the AUC of 0.610 for AHI > 30 events/h in our cohort.

Although the SBQ in AD patients has a sensitivity of 85%, this sensitivity is lower than that for other pathologies. Furthermore, the SBQ has a low specificity for detecting moderate to severe OSA, which can lead to a high percentage of false positives. In addition, an AUC of 0.61 is clearly insufficient for use as a screening tool in this population.

In our analysis, we changed the cut-off points of age, BMI and neck circumference to discriminate more severe OSA status because these are key variables. However, given the age and special characteristics of the target population, these variables require

different weights in the total scale. According to this strategy, we determine a new correction method that we call modified SBQ, and we markedly increased the AUC of the test. Although these data can offer guidance on developing specific screening tests for this population, validation of this proposed test in an independent population is necessary.

BQ was designed to identify patients with OSA in primary care [12]. However, various studies in patients evaluated in sleep units and in different subgroups of the population have shown limited usefulness [31,32].

In our study, the BQ showed a very low sensitivity (4%) for moderate and severe OSA and a high specificity (97% and 96%, respectively). In the general population, BQ showed a wide range of sensitivities from 43% to 89% and specificities from 33% to 79% [33].

The results observed in various population groups markedly differ. In an asthmatic population, the BQ had a sensitivity of 60% and a specificity of 91% for discriminating moderate OSA [34,35]. In patients with mental illness, the BQ showed a similar sensitivity (69%) and a lower specificity (50%) for AHI $\geq$ 15 [13]. Finally, considering other neurological disorders, such as TIA, the sensitivity of the BQ ranged from 56.5% to 90% and the specificity ranged from 14.8% to 100% [28–30].

In brief, BQ for detecting OSA appears to be very specific in AD patients but has too low sensitivity and AUC for use as a screening tool in AD patients. One of the three variables evaluated in the BQ is fatigue. In patients with cognitive impairment, in whom apathy is very frequent, the presence of fatigue can be difficult to differentiate. Thus, accurate data for this variable can be difficult to obtain, hindering the performance of this scale.

A strength of this study is that PSG was used to classify the patients. Very few studies have performed PSG in patients with AD. Yet, the following limitations of this study should be noted: First, AD patients were enrolled from a memory clinic, not from a population-based community. Second, we excluded patients with moderate to severe AD because we believed that the patients would not be able to accurately answer the questions on the screening tests and because realizing PSG would be very difficult. Thus, our conclusions cannot be extended to these patients.

5. Conclusion

In conclusion, this study demonstrates a high prevalence of sleep apnoea in mild AD patients. SBQ is slightly more effective than the BQ for detecting the risk of OSA in patients with AD. The SBQ relies on easily obtained information that can be obtained via objective measures, such as BMI and neck circumference, and subjective questions that can be completed with a partner (very important in patients with cognitive impairment). Alternately, the SBQ has too low specificity and AUC for use as a screening test in this population, and different weights of several variables of the scale are needed to increase its usefulness. For this reason, we proposed a modified version with increased AUC only changing cut-off points and using the same variables than original SBQ. Given the characteristics of patients with AD, it is necessary to increase research in this field to improve early detection and to assess whether possible predictors can be incorporated into new screening questionnaires to improve the diagnosis of OSA in mild AD patients.

Funding

This work was supported by “Fundació La Marató TV3” (Gerard Piñol), Spanish Respiratory Society (SEPAR) and ALLER.

Conflict of interest

The ICMJE Uniform Disclosure Form for Potential Conflicts of Interest associated with this article can be viewed by clicking on the following link: https://doi.org/10.1016/j.sleep.2019.01.014.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.sleep.2019.01.033.

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