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Diagnosis of Sleep-Disordered Breathing in the Home Environment

Edyta Dzięciołowska-Baran, Aleksandra Gawlikowska-Sroka, and Jacek Szczurowski

Abstract

Polysomnography, a gold standard for the diagnosis of sleep-disordered breathing, is a complex investigation requiring access to the sleep laboratory. Thus, sleep-disordered breathing could be underdiagnosed. The aim of this paper was to investigate the feasibility and effectiveness of self-performed investigation of obstructive sleep apnea (OSA) in the home setting, using a portable device, and to assess the comfort and simplicity of the procedure from the patient's perspective. The study included 68 middle-aged patients (21 women and 47 men), who were examined at home with the ApneaLink Air device in search for the underlying reason of reported nighttime snoring and occasionally disordered breathing pattern. The apnea-hypopnea index was quantified and matched with body mass index (BMI), age, and other characteristics. OSA was diagnosed in 37 patients (27 men and 10 women): 22 had mild, 4 had moderate, and 11 patients had severe OSA. All cases of severe OSA were present in men. Patients with severe OSA had significantly higher BMI than those from the other groups. All of the patients pointed to the comfort and ease of the diagnostic device. We conclude that home diagnosis of OSA is a relatively easy and cost-effective way to substitute for the hospital-linked polysomnography, particularly in severely ill patients who have a movement difficulty. A wider implementation of home-based diagnosis of OSA may substantially increase the number of patients investigated in a short time span, also leading to the plausibly upward correction of the disease prevalence.

Keywords

Disordered breathing · Portable diagnostic device · Self-diagnosis · Sleep apnea · Sleep-disordered breathing

E. Dzięciołowska-Baran (✉)
Department of Anatomy, Pomeranian Medical University in Szczecin, Szczecin, Poland

Department of Otolaryngology, Provincial Hospital, Szczecin, Szczecin, Poland
e-mail: edyta.dzieciolowska@pum.edu.pl

A. Gawlikowska-Sroka
Department of Anatomy, Pomeranian Medical University in Szczecin, Szczecin, Poland

J. Szczurowski
Department of Anthropology, Biology Institute, Wrocław University of Environmental and Life Sciences, Wrocław, Poland

1 Introduction

Sleep-disordered breathing is a heterogeneous group of conditions causing the disruption of physiological sleep. The first sign of a disorder is snoring. Sometimes it is a lone symptom but often is accompanied by hypopnea which, in turn, is a harbinger of apneic episodes. Apnea is diagnosed when breathing ceases for longer than

10 s and occurs more frequently than five times per hour. Sleep apnea is classified into three grades depending on the number of apneic episodes per hour: mild, 5–15; moderate, 16–30; and severe, >30 episodes. Arterial blood oxygen saturation decreases during sleep apnea, which makes sleep-disordered breathing a serious, health-threatening, and potentially lethal disease. Repetitive waking arousals make night rest ineffective, dysregulate blood pressure and metabolic controls, lead to daytime sleepiness, and reduce cognitive performance and overall quality of life (Sjösten et al. 2009).

The most common type of sleep apnea, accounting for *ca*. 85% of cases, is obstructive apnea (OSA), in which airways become narrowed or obstructed due to a collapse of the pharyngeal muscles due to either dysfunction of neural activity running down from the brain or local thickening of surrounding fatty or lymphatic tissues. The much rarer central sleep apnea, unconnected to a narrowing of airway lumen, is usually driven by cerebrovascular-related causes (Javaheri 2005; Javaheri et al. 2017). The incidence of OSA in the population of highly developed countries is 2–5% among middle-aged women, 3–7% in men, and over 12% in older men (Jennum and Riha 2009; Duran et al. 2001). That is, however, most likely a gross underestimation as apneic episodes are easily missed and thus the disease is undiagnosed (Simpson et al. 2013). One reason for the situation is insufficient access of patients to professional diagnosis which requires overnight sleep monitoring. This investigation is performed when a suspicion of the disease arises, most often on the basis of nighttime breaks in breathing noticed by the patient's partner (Kunisaki et al. 2016). Polysomnography remains the gold standard for the diagnosis, requiring a hospital setting, being pricey and complex, and rather uncomfortable for the patient. There has been an apparent need for easier and more cost-effective methods of sleep monitoring, usable for large-scale screening, in particular avoiding a complexity of in-hospital stay. Some older studies showed that home self-investigation toward the diagnosis of OSA may be of high value, with sensitivity as high as 90% (Flemons et al. 2003). Recent technological advances in portable and remote medical care have made the home diagnosis of OSA an effectively developing area of investigation.

The goal of this study was to determine the diagnostic feasibility of an automated portable device for the monitoring of breathing pattern at sleep in the home. We analyzed the value of information acquired from the home sleep and breathing investigation for the diagnosis of sleep-related breathing disorders. We also gathered the patients' opinion regarding such a home-based investigation, with particular emphasis on the simplicity of use and the patient's comfort.

2 Methods

There were 68 patients enrolled into the study: F/M – 21 (31%)/47 (69%). The patients were seen by ear, nose, and throat (ENT) specialists due to suspected sleep-disordered breathing, such as frequent, occasional, or regular snoring, shallow breathing, or episodes of breathlessness reported by bed partners. The mean age was 54.0 ± 13.6 years in women (33–82 years) and 47.0 ± 9.9 years in men (range 22–74 years). The difference in age between women and men was significant ($p < 0.05$), and it showed that older women are by no means spared from snoring and suspicion of sleep-disordered breathing. Both snorers and their partners were surveyed using separate questionnaires, designed specifically for this study. The questionnaire for the snorer consisted of 31 items that concerned the demographic and anthropometric features, the type of breathing distress at sleep, a degree of disturbance and embarrassment it caused, recent changes in the patient's body mass, and if there was such a change, how it affected the respiratory distress. The questionnaire for the partner consisted of items concerning the type of breathing disorders noticed and the willingness and motives to help the patient in further medical procedures to resolve the health issue. These preliminary questionnaires were a requirement to qualify for

a portable diagnostic device to be taken home by the patient. The survey answers were not subject to statistical evaluation nor were they matched with the results of diagnostic tests.

Each patient obtained an ApneaLink Air recorder (ResMed, Warsaw, Poland) to use it in the comfort of one's own bedroom, along with verbal and printed instructions and basic training on how to use it for sleep monitoring during a night. The recorder is a lightweight portable sleep testing device that is capable of recording up to five channels of information: respiratory effort, heart pulse, oxygen saturation, nasal flow, and snoring. The device needs to be assembled with a chest belt, pulse oximeter, and a nasal cannula to measure the airflow during breathing. The cannula is connected to a pressure transducer, providing an apnea-hypopnea index (AHI) per hour of the sleep recording time. Aside from AHI, the device is capable of automated analysis of the hypopnea index, airflow limitation, snoring, and oxygen desaturation index, and it distinguishes obstructive from central apneic episodes. The variables recorded have configurable thresholds, meeting the recommendations established for hypopnea scoring by the American Academy of Sleep Medicine and the Centers for Medicare and Medicaid Services. The device also is capable of detection of Cheyne-Stokes breathing pattern and helps identify patients who should be referred to an in-lab sleep study. The device also allows manual scoring if required for a recheck of data. After the completed overnight test, the device was returned to the healthcare provider, and an easy-to-interpret report was generated with a color-keyed AHI or risk indicator, which was subsequently discussed with the patient.

Data were expressed as means ±SD. Distribution of variables that was checked with the Shapiro-Wilk test was calculated. Differences between the arithmetic means of independent variables with normal distribution (age of patients) were assessed with Student's *t*-test. For the AHI data, which showed a skewed distribution, the Mann-Whitney U test was used. Differences in the mean values of AHI depending on age and BMI were assessed with one-way ANOVA and a post hoc least significant difference (LSD) test. A p-value <0.05 defined statistically significant differences throughout the analysis.

3 Results

3.1 Apnea-Hypopnea Index (AHI) Depending on Gender, Age, and Body Mass Index (BMI)

Overall, OSA was detected in 37 (54.4%) patients, in detail in 27 out of the 47 men and in 10 out of the 21 women, out of the 68 study subjects. There were 11 (7.6%) patients with severe OSA (AHI = 43.3 ± 10.9 episodes *per* hour), all of them being men. Thirteen men had mild OSA (AHI = 9.2 ± 2.5 episodes *per* hour) and another three had moderate OSA 18.6 (AHI = 18.6 ± 1.5 episodes *per* hour). Mild OSA was detected in 9 women (AHI = 7.7 ± 2.5 episodes *per* hour), and another 1 woman had moderate OSA (AHI = 7.2 ± 2.5 episodes *per* hour), and another 1 woman had moderate OSA with AHI of 15.8 episodes *per* hour.

Taking both men and women OSA patients together, the mean age of patients was 52.4 ± 11.4 years in mild OSA, 62.8 ± 10.9 years in moderate OSA, and 48.2 ± 8.5 years in severe OSA. The age differed among these three groups of OSA severity was significant, being significantly greater in moderate OSA than that in severe OSA. It was also greater than that the age of healthy subjects ($p < 0.05$; one-way ANOVA with post hoc LDS). Concerning the BMI, it was significantly greater in patients suffering from mild and severe OSA than that in the healthy subjects, with the apparent lack of a significant difference between the patients with moderate OSA and healthy subjects ($p < 0.01$; one-way ANOVA with post hoc LDS) (Table 1).

Table 1 Distribution of study patients by apnea-hypopnea index (AHI), age, and body mass index (BMI)

	AHI	Age (years)	BMI (kg/m^2)
Healthy ($n = 31$)	2.4 ± 1.2 (0.5–4.6)	46.0 ± 14.3 (22–66)	26.7 ± 3.5 (22.1–35.6)
OSA ($n = 37$)			
Mild ($n = 22$)	8.6 ± 2.6 (5.0–13.1)	52.4 ± 11.4 (33–82)	30.4 ± 4.7 (21.6–41.8)
Moderate ($n = 4$)	17.9 ± 1.9 (15.8–19.6)	62.8 ± 10.9 (48–74)	26.0 ± 2.2 (23.1–28.4)
Severe ($n = 11$)	43.3 ± 10.9 (32.2–65.5)	48.2 ± 8.5 (34–60)	32.7 ± 5.9 (43.6–34.5)

Data are means ±SD. *AHI* apnea-hypopnea index (episodes *per* hour of sleep time), *OSA* obstructive sleep apnea, *BMI* body mass index

3.2 Assessment of the Patient's Experience with Performing the Sleep Test

Upon the return of the ApneaLink Air device, patients were asked to describe their experience with using it. Only did one patient give negative comments, complaining about the complicated way of using the switches, but despite the trouble he managed to complete the examination. Forty-six patients (67.6%) assessed the comfort and ease of using the device very well. Twenty-two subjects (32.4%) expressed a positive opinion, mentioning only a minor discomfort associated with the attachment of a nasal cannula and the fear of oximeter sensor slipping off the finger. Four out of these patients also were confused by the flashing diode and were unsure whether the device was on or off. Some patients were also somehow emotionally stressed because of being tested at sleep. In general, the device did not restrict changing the body position at sleep, nor did it disturb sleep in any way. Comparison by patients of the ApneaLink Air device to Holter blood pressure or hear rate testing came out advantageous to the former.

The data acquired indicate that breathing disorders during sleep in women tended to occur at a later age but were milder than those in men, although the incidence of OSA noticed in this study was lower in women than men. The analysis of the age structure of patients with sleep-disordered breathing demonstrates, in general, the association of OSA with age. Interestingly, however, patients with most severe OSA were younger than those with moderate OSA (48.2 ± 8.5 vs. 62.2 ± 10.9 years of age, respectively), even though a reverse relationship was noted concerning BMI (Table 1). In fact, the most senior patients with moderate OSA appeared physically quite lean as their BMI was within the normal range, comparably to the healthy subjects.

All of the tested patients who were diagnosed with OSA or snoring were offered guidance concerning further diagnostic procedures and management. Subjects with abnormal BMI were advised about nutritional measure and physical activity enhancing interventions to lose weight. Some of the overweight and obese patients qualified for corrective surgery of the soft palate or nasal patency, but the decision was delayed until after the achievement of body weight reduction. Polysomnography was recommended in a few patients with moderate and severe OSA in whom the pathogenesis of the disease appeared more complex. This group mostly included patients with coexisting cardiovascular diseases.

4 Discussion

The use of home sleep monitoring devices for the diagnosis of breathing disorders at sleep has been the subject of a lasting debate. The most debatable issue has been of whether such devices may merely help detect a breathing problem or could be used to set the final diagnosis, based on which a specific treatment could be implemented. Another issue is the diagnostic sensitivity of such devices and whether every patient could be self-tested with a portable device and if not what would be the selection of patients for this kind of testing. To answer these questions, the results obtained with portable devices have been compared to those

from polysomnography (Pack 2015). According to the recommendations of the American Sleep Disorders Association (ASDA), polysomnography is the ultimate method for the diagnosis of sleep-disordered breathing. It is much more sensitive than other tests are since it provides a host of recordings of variables during natural sleep, including the electroencephalogram (EEG), electromyogram (EMG), electrooculogram (EOG), electrocardiogram (ECG), airflow, respiratory movements of the thorax and abdomen, arterial oxygen desaturation, snoring, and others. Such a complex analysis cannot be done with portable sleep monitoring devices. The ASDA distinguishes four types of monitoring devices depending on the number of channels recording information. Level I devices are eight-channel monitors (EEG, EOG, ECG, EMG, airflow, respiratory effort, oxygen saturation, body position). Level II devices are seven-channel monitors (EEG, EOG, chin EMG, ECG or heart rate, airflow, respiratory effort, and oxygen saturation). Level III devices are four-channel monitors, but they do not cover EEG, and the simplest level IV devices record one or two variables, which usually are airflow and oxygen saturation.

Polysomnography belongs to Level I category. The advocates of polysomnography emphasize its better sensitivity and specificity, when compared to home sleep testing, which translates into the more effective treatment planning of OSA, which is of particular importance in the case of continuous positive airway pressure (CPAP) therapy (Pack 2015). The opponents, on the other side, point to the high diagnostic costs of using polysomnography and postulate the use of home sleep testing instead, as in the case of severe OSA with a high AHI, the diagnostic yield is comparable with the use of either (Freedman 2015). The opponents, or rather those who are distrustful of HST, draw attention to the fact that superficial, simplified perception solely based on the costs of the diagnostic test is a short-sighted strategy, and the economic benefits associated with the identification and treatment of patients, as well as the costs of misdiagnosis should be considered. The opponents particularly focus on the effective treatment and argue that polysomnography remains "the cornerstone for diagnosis in patients suspected of having comorbid sleep disorders, unstable medical conditions, or complex sleep-disordered breathing" (El Shayeb et al. 2014).

The ApneaLink Air device has been available for several years. The device records up to five channels of information. Nonetheless, it appears fairly effective in detection of sleep-disordered breathing, with sensitivity and specificity of at least 80% for AHI of ten episodes *per* hour of sleep. The greatest sensitivity and specificity of 91% and 95%, respectively, were found for AHI $\geq$15 episodes *per* hour. At AHI >10 episodes *per* hour, specificity decreases leading to a greater number of false-positive results (Erman et al. 2007). Thus, the device seems most useful for OSA screening in high-risk adults, e.g., obese patients with metabolic disorders, which helps implement a prompt treatment. Notably, there also is a promising report on the use of ApneaLink Air in pediatric patients with obesity and suspected OSA (Lesser et al. 2012). That study involved 25 children and adolescents aged 9–18 years with BMI $\geq$95th percentile for age/gender, all of whom were regular snorers. The authors point to the accuracy of the device, comparably to that of polysomnography, in the identification of OSA and to its sensitivity even at low AHI values. That is a finding that underscores the utility of portable screening devices in view of the increasing obesity in children and its relation to the development of OSA. An early diagnosis and treatment of OSA in children is essential for counteracting the impact of the disease on neurocognitive functions and the risk of cardiovascular complications in adulthood.

ApneaLink Air has also been reported to unravel the presence of central breathing disorders, particularly of the Cheyne-Stokes type (Weinreich et al. 2009). Such breathing disorders often occur in patients with cerebrovascular pathologies, damage to the respiratory brain stem network, or opiate and barbiturate overuse. The device is recommended for the diagnosis of mixed central and peripheral episodes of airway obstruction, making it a sensitive pretest that enables the prioritization of such patients for polysomnography.

In conclusion, a self-screening of nighttime respiration in the home setting, using a mobile device, is useful for the diagnosis of sleep-disordered breathing. The major advantages of such screening include a good sensitivity and specificity of testing, a good cost-effectiveness ratio, simplicity and convenience of testing and data analysis, and a good compliance of patients. Such screening also is useful in a prompt identification of patients who would be suitable candidates for the full-fledged in-lab sleep polysomnography study.

Conflicts of Interest The authors declare no conflicts of interest in relation to this article.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The study was approved by the Bioethics Committee of the Pomeranian Medical University in Szczecin, Poland.

Informed Consent Written informed consent was obtained from all individual participants included in the study.

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