Auditory Function of Patients with Obstructive Sleep Apnea Syndrome: A Study

Mustafa Sitki Gozeler, Furkan Sengoz

ABSTRACT

Objective: Obstructive sleep apnea syndrome (OSAS) is a respiratory syndrome that manifests during sleep. For the auditory system to be able to function normally, the inner ear and cochlear nerve require healthy oxygen support. The purpose of this study was to assess the hearing function of patients with OSAS and to reveal the relationship between polysomnographic parameters and hearing test results.

Materials and Methods: The study was performed with 35 patients diagnosed with moderate or severe OSAS using polysomnography and a control group consisting of 30 individuals. The snoring, tiredness, observed apnea, blood pressure, body mass index, age, neck circumference and gender (STOP-Bang) questionnaire was used to establish the control group. Detailed otoscopic examinations were administered to all subjects by the same otolaryngologist, followed by a tympanogram, pure-tone audiometry (PTA) and transient evoked otoacoustic emissions (TEOAE) tests.

Results: We determined mild sensorineural hearing loss in patients with OSAS. When the different frequencies were evaluated separately, hearing threshold values in the patients with OSAS were significantly higher compared to the control group at 500, 1000, 2000, 4000, and 8000 Hz in both ears. TEOAE test reproducibility values in both ears were significantly lower in the study group compared to the control group.

Conclusion: The hearing system is affected to varying degrees in patients with OSAS. If hearing loss is detected in patients presenting at otolaryngology clinics due to snoring, then assessing these subjects in terms of risk of OSAS is important to reduce mortality and morbidity that may develop at later stages in association with OSAS.

Keywords: Audiometry, hearing, obstructive sleep apnea syndrome, pure-tone, transient evoked otoacoustic emissions

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Department of Otorhinolaryngology, Ataturk University School of Medicine, Erzurum, Turkey

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Correspondence to: Mustafa Sitki Gozeler
E-mail: msgozeler@gmail.com

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Introduction

Obstructive sleep apnea syndrome (OSAS) is a respiratory disorder that manifests during sleep. It is characterized by a recurring obstruction of the upper airways that results in high levels of morbidity and mortality due to its effect on several systems, particularly the cardiovascular and neurological systems. It is seen in 4% of men and 2% of women in the middle-age group [1]. Prolonged nightly apnea-hypopnea attacks result in intermittent hypoxia, which plays a key role in the development of various complications. Oxidative stress occurs as a result of chronic hypoxia, and vascular endothelial functions can also be compromised. In addition, the vasa nervorum can be damaged as a result of hypoxia. Irreversible peripheral neuropathy develops in association with intermittent hypoxia [2].

For the auditory system to function normally, the inner ear and cochlear nerve require healthy oxygen support. Conditions that lead to hypoxia can cause various levels of hearing loss by impairing the auditory system [1, 2].

The purpose of this study was to assess the hearing functions of patients with OSAS and to reveal the relationship between polysomnographic parameters and hearing test results.

Materials and Methods

Ethical approval was granted from the Ethical Committee of Ataturk University, Faculty of

Medicine (approval number: 2017:5:4). Patients diagnosed with moderate or severe OSAS (Apnea-Hypopnea Index (AHI)>15) based on the results of polysomnography tests performed in the Sleep Laboratory of Ataturk University were included in the study. Informed consent was obtained from all patients. The snoring, tiredness, observed apnea, blood pressure, body mass index, age, neck circumference and gender (STOP-Bang) questionnaire (SBQ) developed by Chang et al. [3] was used to establish the control group.

The SBQ is extensively employed as an accurate screening test for OSAS. The questionnaire comprises four yes/no questions concerning habitual snoring, tiredness/sleepiness, observed apnea, and high blood pressure. Each affirmative response received a score of 1. A further score of 1 was added for each of the following clinical characteristics: body mass index >35 kg/m^2, age >50 years, neck circumference >40 cm, and gender being male. Scores of 3 or more from a maximum possible total of 8 were considered to represent a high risk of OSAS. Patients who were determined to be at low risk of OSAS by the SBQ formed the control group. Detailed otoscopic examinations were administered to all subjects by the same otolaryngologist, followed by a tympanogram, pure-tone audiometry (PTA) and transient evoked otoacoustic emissions (TEOAE) tests. Subjects with a personal or family history of hearing loss, a history of ototoxic drug use or having chronic diseases such as hypertension and diabetes were excluded from the study.

Polysomnography

Full polysomnography analysis was performed using the Compumedics E-series Sleep System (Compumedics Sleep, Melbourne, Vic., Australia). Electroencephalography (EEG), electrooculography, electromyography, and electrocardiography tests were carried out concurrently. Surface electrodes were attached in order to measure EEG channels, right and left electrooculography readings, and submental electromyography. Nasal or oral respiratory flow was calculated using airflow mask. Inductive plethysmography bands were used to monitor thoracic and abdominal respiratory movements and the position of the body. Arterial oxygen saturation for pulse oximetry was measured from the patients' fingertips.

Apnea was defined as the continuous cessation of airflow greater than 10 seconds in duration and hypopnea was defined as 30% reduction in airflow for a duration greater than 10 seconds accompanied by an oxygen desaturation value of ≥3% or reduced thoracic wall movement. The AHI was defined as the total number of apnea and hypopnea events per hour of sleep.

Tympanogram

These tests were performed with Interacoustics AT 235h tympanometer (Interacoustics, Middelfart, Denmark). Subjects with type B and C tympanogram readings were excluded from the study for the purpose of eliminating those who may have pathological conditions in the middle ear.

Pure-tone Audiometry

These tests were administered to all subjects by an experienced audiologist using a Maico MA53 audiometer (Maico Diagnostics, Berlin, Germany) inside a sound-proofed chamber. Subjects were directly exposed to a range of different frequencies and amplitudes. Subjects were instructed to lift their hands or press a button as soon as they perceived the sound tone. The lowest response level achieved was adopted as the threshold value for each separate frequency. Air thresholds were calculated at frequencies of 250, 500, 1000, 2000, 4000 and 8000 Hz and bone threshold values were recorded at 500, 1000, 2000, 4000 Hz. The hearing thresholds recorded in the study group at each separate frequency were compared with the equivalent value measured in the control group. The mean hearing thresholds for both groups were calculated by dividing by 3 those thresholds that were frequencies of 500, 1000, and 2000 Hz.

Transient Evoked Otoacoustic Emissions

All TEOAE tests were carried out by an experienced audiologist in a sound-proofed chamber with a Vivosonic Integrity Evoked Potentials System device (Vivosonic Inc., Toronto, Canada). A click stimulus was used. The signal/noise ratio (SNR) was calculated at four distinct frequencies (1 kHz, 2 kHz, 3 kHz, 4 kHz). The SNR values recorded in the study and control groups were measured for each frequency and subsequently subjected to a comparative analysis. The SNR represents the difference between the emission amplitude and the noise floor. In addition, signal amplitude values and test reproducibility values were recorded for each subject.

Power Analysis

The preliminary outcome of the study was the difference in the hearing thresholds. In our preliminary study, the standard deviation was determined as 5.9 in the study group and 5.1 in the control group. The expected difference in the hearing threshold was at least 10 dB. Accordingly, with 35 patients in the OSAS group and 30 individuals in the control group, the power of the study was calculated as 99%, with an alpha error of 0.05 using the Russ Lenth Piface Java Module.

Statistical Analysis

Statistical Package for the Social Sciences 17.0 software (SPSS Inc.; Chicago, IL, USA) was used for statistical analysis. Data were expressed as a mean±standard deviation. The Shapiro-Wilk test was used to determine the distribution of data. The student's T-test was used for comparisons in the case of normal distribution and the Mann-Whitney U test under non-parametric conditions. For correlation analysis, Pearson's or Spearman's correlation tests were used to determine if the data is well-modeled by normal distribution. $p<0.05$ was regarded as significant for all tests.

Results

The study was performed with 35 patients aged 39-48 (44.4±3.9) years diagnosed with moderate or severe OSAS at polysomnography tests and a control group consisting of 30 individuals aged 28-51 (43.1±2.4) years who were identified as having a low risk of OSAS based on the SBQ. 20 men and 15 women were included in OSAS group while 17 women and 13 men were included in control group. There was no statistically significant difference between the two groups in terms of age or sex. There was no statistically significant difference between the body mass index of the control group (27.5±2.2) and OSAS group (28.3±1.9) ($p=0.06$). Mean AHI in the OSAS group was 37.7±21.9. Demographic characteristics and polysomnography data for individuals in the OSAS and control groups are shown in Table 1.

Mean hearing thresholds based on audiogram results in the OSAS group were 23.7±5.9 in

Table 1. Comparison of demographic properties and polysomnographic parameters of OSAS and control groups

	Control (n=30)	Study (n=35)	p
Age	43.1±2,4	44.4±3.9	0.16
Gender (M/F)	13/17	20/15	0.6
BMI	27.5±2.2	28.3±1.9	0.06
AHI		37.7±21.9	
SpO_2		87.9±4	
TST		345±53.5	
Desaturation Ratio		6.2±2.7	
TST90		146±106.1	

BMI: Body mass index; AHI: Apnea/hypopnea index; TST: Total sleep time; TST90: Sleep time at an oxygen saturation less than 90%

Table 2. Mean hearing levels for each frequency

	RIGHT EAR			LEFT EAR		
Frequency (Hz)	Patients	Control	p	Patients	Control	p
250	17±8.3	15.2±6.9	0.48	18.3±11.6	13.4±7.1	0.10
500	22.3±10.6	12.8±6.6	<0.05*	21.9±11.3	10.8±4.7	<0.01*
1000	23.6±12.3	12.2±5.6	<0.01*	22.1±11.5	9.6±5.5	<0.01*
2000	24.9±12.5	10.4±5.1	<0.01*	23.3±12	8±5.4	<0.001*
4000	28.5±15.1	14±6.9	<0.001*	30.4±15	13.2±6.9	<0.001*
8000	29.3±16.6	19.4±10.7	<0.05*	36.2±17.2	22±17.9	<0.01*
Mean	23.7±5.9	12.3±5.1	<0.001*	22.9±6.6	9.4±4.6	<0.001*

* Statistically significant (Mann–Whitney U test)

Table 3. TEOAE SNR levels

	RIGHT EAR			LEFT EAR		
Frequency (Hz)	Patients	Control	p	Patients	Control	p
1000	5.3±3.2	8.5±4.5	0.01	6.7±3.2	9.7±4.5	0.01
2000	5.5±4.3	8±2.9	0.09	6.8±3.2	8.2±3.3	0.21
3000	7.1±2.8	7.5±4.4	0.62	5.4±3.4	5.9±3.1	0.46
4000	6.2±3.1	4±3.8	0.01	5.4±3.3	6.4±5.6	0.77
Reproducibility	60±12.6	70.1±8.1	<0.01*	58.1±18.6	68.4±6.5	<0.05*

TEOAE: transient evoked otoacoustic emissions; SNR: signal/noise ratio; *: Statistically significant (Mann–Whitney U test)

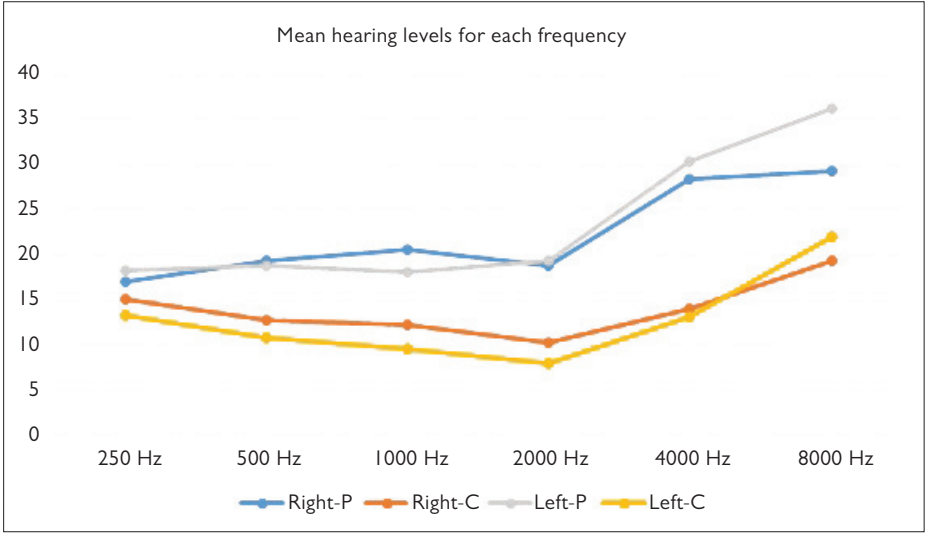

Figure 1. Audiological results of OSAS and control group

the right ear and 22.9±6.6 in the left ear, compared to control group values of 12.3±5.1 in the right ear and 9.4±4.6 in the left ear (Table 2). Mean hearing thresholds in both ears were significantly higher compared to the control group (p<0.001, Mann- Whitney U test). There was no difference in terms of bone thresholds between groups and no air-bone gap was observed at PTA tests.

When frequencies were examined separately, hearing thresholds at both ears in the OSAS group at 500, 1000, 2000, 4000 and 8000 Hz were significantly higher compared to the control group (Figure 1).

Evaluation of TEOAE values revealed no statistically significant variation between SNR values and signal amplitudes in the two groups. However, test reproducibility values in the OSAS group were 60±12.6 in the right ear and 58.1±18.6 in the left ear, compared to 70.1±8.1 in the right ear and 68.4±6.5 in the left ear in the control group. Test reproducibility values in both ears were significantly lower compared to the control group (right ear p<0.001, left ear p<0.05, Mann-Whitney U test). TEOAE test parameters are summarized in Table 3.

When hearing thresholds were compared with polysomnography data, no significant correlation was observed between AHI, SpO_2, total sleep time (TST), sleep time at an oxygen saturation less than 90% (TST90) or mean desaturation values and hearing thresholds and TEOAE values.

Discussion

We determined a mild sensorineural hearing loss in patients with OSAS. When the different frequencies were evaluated separately, hearing threshold values in the patients with OSAS were significantly higher compared to the control group at 500, 1000, 2000, 4000, and 8000 Hz in both ears. No statistically significant difference was observed in TEOAE test results between the patient and control groups in terms of SNR or amplitude values. However, test reproducibility values in both ears were significantly lower in the study group compared to the control group. Additionally, no correlation was observed between hearing threshold levels and the polysomnographic parameters (AHI, SpO_2, TST, TST90) and mean desaturation values.

OSAS is a prevalent respiratory disorder characterized by snoring and breathing attacks caused by airway obstruction during sleep. It can cause complications in several organ systems in association with ischemia and intermittent hypoxia which inevitably develop due to recurring apnea attacks. A few studies have investigated the effects of OSAS on the hearing system, but their results are inconsistent.

Hwang et al. [4] reported that the presence of OSAS does not affect hearing thresholds. In their study of patients with OSAS, Martines et al. [5] reported that the hearing thresholds of OSAS patients at extended high frequencies were significantly higher than those of patients with simple snoring. However, they also reported that mean hearing thresholds between the frequencies of 250 and 8000 Hz did not differ between individuals with OSAS and simple snoring. At the TEOAE test, significantly lower SNR values were determined only at frequencies of 3000 and 4000 Hz between the severe OSAS and simple snoring groups. In contrast to that study, we compared OSAS patients to healthy individuals at no risk of OSAS by establishing a control group based on the STOP-BANG questionnaire. Our results

showed a significant elevation in hearing thresholds at frequencies of 1000-8000 Hz in OSAS patients as compared to the control group. We observed no difference after the TEOAE test between the groups in terms of SNR and amplitude values.

Casale et al. [6] reported that mean hearing thresholds were within normal limits in patients with OSAS, but that these were significantly higher than those of the control group. Additionally, when individual frequencies were analyzed, hearing thresholds at 4000 Hz were significantly higher than those of the control group. In the TEOAE test, they observed significantly lower reproducibility and SNR values in patients with OSAS compared with the control group. Similarly, Matsumura et al. [7] observed no significant difference between groups in terms of mean hearing thresholds but determined significantly higher hearing thresholds at high frequencies of the OSAS group as compared to the control group. Ballaccihino et al. [8] determined significantly high hearing loss in individuals at risk of OSAS with the STOP-BANG questionnaire and significantly low SNR values using the TEOAE test. Ekin et al. [1] reported that hearing thresholds were not affected at low and high frequencies in individuals with OSAS and/or simple snoring compared to the control group, but observed significantly high hearing thresholds at extended high frequencies. When subjects with simple snoring and the OSAS were compared, however, they determined no difference in hearing thresholds at any frequencies.

The subject of how OSAS affects the hearing system is still controversial. Steiner et al. [9] reported that blood plasma viscosity increases in patients with OSAS and that this compromises microcirculation. Bernand et al. [10] also reported that this hyperviscosity can lead to impairment of the hearing system. In contrast, Casale et al. [6] reported that the adverse effect of OSAS on the hearing system may be due to intermittent hypoxia and ischemia associated with repeated obstruction of the airways. Ekin et al. [1] suggested that hearing loss was the result of exposure to constant noise from snoring rather than the occurrence of hypoxia.

The most important limitation of our study is that extended high frequencies were not studied in audiogram tests. The fact that no investigation was made of the pathogenesis of hearing loss in OSAS is another limitation.

In conclusion, the auditory system is affected in varying degrees in patients with OSAS. In the event that hearing loss is detected in patients presenting at otolaryngology clinics due to snoring, it is important to assess these subjects and determine their risk of OSAS to reduce the mortality and morbidity that may develop at later stages in association with OSAS.

Ethics Committee Approval: Ethics committee approval was received for this study from the ethics committee of Ataturk University School of Medicine (2017:5:4)

Informed Consent: Written informed consent was obtained from patients who participated in this study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - M.S.G., F.S.; Design - M.S.G., F.S.; Supervision - M.S.G., F.S.; Resources - M.S.G., F.S.; Materials - M.S.G., F.S.; Data Collection and/or Processing - M.S.G., F.S.; Analysis and/or Interpretation - M.S.G., F.S.; Literature Search - M.S.G., F.S.; Writing Manuscript - M.S.G., F.S.; Critical Review - M.S.G., F.S.

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