

Evaluation of auditory functions in patients with asthma

T. KILIC, E. KARATAS¹, Y. TOPLU¹, A. KOC¹, N. BULAM¹, O. KAYA

Department of Pulmonary Medicine, Inonu University Faculty of Medicine, Turgut Ozal Medical Center, Malatya, Turkey

¹Department of Otorhinolaryngology and Head and Neck Surgery, Inonu University Faculty of Medicine, Turgut Ozal Medical Center, Malatya, Turkey

Abstract. – OBJECTIVE: The objective of this study is to evaluate the auditory functions in chronic asthma patients with the use of pure tone high frequency audiometry.

PATIENTS AND METHODS: Twenty-two healthy controls and 42 adult patients were included as a prospective, randomized, and controlled study. Pulmonary function tests and blood gas studies were completed on all subjects. Asthma patients have divided into two groups [Group A: Arterial oxygen tension (PaO₂) > 75 mmHg, Group B: PaO₂ ≤ 75 mmHg, Group C: Control group]. Acoustic assessments of patients were performed in 250-20000 Hz by using pure-tone audiometry (PTA) and tympanometry.

RESULTS: The mean value of air and bone conduction hearing threshold levels were in normal range for all groups. All patients had normal peripheral hearing all threshold levels across 250 Hz to 3000 Hz in the both ears. Significant differences were observed between the chronic asthma patients and control group for the extended high frequencies (10000-20000 Hz). Group B had statistically more significant increased hearing threshold levels than Group A in frequencies higher than 10000 Hz. There were no statistical differences between the hearing threshold levels and FEV₁, FVC, FEV₁/FVC and tympanogram results in the groups.

CONCLUSIONS: This is the first study of evaluating the auditory functions in asthma patients. Sensorineural hearing loss in high frequencies (10000 Hz-20000 Hz) is common in chronic asthma and is probably present more often than were formerly thought.

Key Words:

Hearing loss, Asthma, Hypoxia, High frequency.

Introduction

Asthma is a common chronic inflammatory disease of the airways characterized by variable and recurring symptoms, reversible airflow ob-

struction and bronchospasm¹. Common symptoms include wheezing, coughing, chest tightness, and shortness of breath. In addition, patients with asthma have uneven ventilation, which results in arterial hypoxemia and hypercapnia (rarely)².

The prevalence of asthma has increased markedly and asthma is now recognized as a major cause of disability, medical expense, and preventable death. Patients with chronic asthma may remain in a hypoxic state with few symptoms³. Therefore, some other organs may susceptible during the course of the disease. Moreover, diseases that cause hypoxia or ischemia, such as embolism and vascular disease, could also induce hearing loss^{4,5}. Hypoxemia has a direct effect on the cochlea and an indirect effect by way of cardiovascular collapse and cerebral ischemia, leading to sensory or sensorineural hearing impairment⁴. Numerous investigations have documented the presence of auditory symptoms in various chronic lung diseases such as bronchiectasis, interstitial pulmonary fibrosis, bronchopulmonary dysplasia, bronchiolitis obliterans, sequestrated lung disease, or cystic fibrosis⁵. Auditory functions in patients with asthma have not been reviewed in the literature yet.

Hearing loss is not a common symptom in asthma patients, but may probably present more often than was formerly thought. However, there is no any article that describe hearing loss in asthma; therefore, this subject is not a well-known issue for many otolaryngologists and pulmonologists. Pure tone audiometry test is the first step of the diagnosis of hearing loss. This is derived from a subjective hearing assessment across a conventional frequency range of 0.25-8 kHz. Although frequencies below 8 kHz are known to be most important for speech intelligibility, higher frequencies (> 8 kHz) also have an important role in the detecting of an early hear-

ing loss. High frequencies hearing loss is also related with an early damage in the lower part of the cochlea. In the present study, we compared pure tone thresholds for frequencies from 250 Hz to 20 kHz in the patients with asthma to determine a possible hearing loss.

The objective of this study is to compare the auditory functions in chronic asthma patients with healthy controls with the use of pure tone high frequency audiometry and impedance audiometry.

Patients and Methods

The study was conducted as a prospective, randomized, and controlled study. The Ethics Committee of our Faculty approved it (31.07.2012, 2012/121, clinical research Ethics Committee of Inonu University, School of Medicine), and written informed consent was obtained from each patient and healthy controls in accordance with the ethical principles for human investigations, as outlined in the second Helsinki Declaration.

Twenty-two healthy controls and 42 adult patients with asthma who were regularly followed by the Department of Pulmonology were included in this study. Patients were defined as asthma by Global Initiative for Asthma (GINA) recently updated guidelines¹. Furthermore, these were controlled or partially controlled asthma patients according level of GINA asthma control. Pulmonary function tests and blood gas studies were completed on all subjects. Arterial blood gas samples were measured by using the (Siemens RAP D lab[®] 1265, Siemens Healthcare Diagnostics, Erlangen, Germany) heparinized arterial blood sampling system. Arterial oxygen tension (P_aO_2), arterial carbon dioxide tension (P_aCO_2), arterial oxygen saturation (S_aO_2), pH, and arterial blood bicarbonate (HCO_3) values were recorded in the blood samples. The forced expiratory volume in one second (FEV_1), the forced vital capacity (FVC) and FEV_1/FVC were measured by means of a computerized spirometer device (Vmax 22: SensorMedics, Yorba Linda, CA, USA). Asthma patients have divided into two groups (Group A, B) according to the P_aO_2 in the arterial blood gas samples. Group A patients has P_aO_2 over 75 mmHg, group B has P_aO_2 under 75 mmHg and group C has control group.

All patients underwent a standardized intake assessment including a perfect history and physi-

cal examination by an otolaryngologist. The patients younger than 18 years of age and older than 51 years old, bilateral and non-tonal tinnitus, objective tinnitus, middle or external ear problem, otosclerosis, chronic otitis media, vestibular schwannoma, Meniere's disease, history of previous ear and neurologic surgery, history of temporal bone trauma, endocrinological disease, psychiatric disorder, pregnant were excluded from this study. Also, of the patients had no history of drugs with potential inner ear toxicity. All the participants were subjected to careful ear examination to identify any abnormalities that may interfere with hearing such as a perforated tympanic membrane or other middle ear pathologies.

Acoustic assessments of patients were performed by using pure-tone audiometry (PTA) (Interacoustics AC 40, Clinical Audiometer, Assens, Denmark) and by tympanometry (Interacoustics AZ T, Impedance Audiometer, calibrated to ANSI S3.39-1987 standards, Assens, Denmark) for both ears in a double walled sound attenuated suite. Conventional PTA was performed for each subject (device: audiometer AC 40, with earphone TDH 39) in an acoustic chamber meeting criteria of ANSI 2004 at the following frequencies: 500, 1000, 2000, 3000, 4000, 6000, and 8000Hz⁶. Then extended HFA was performed for all subjects with the same device and earphone R80 at 10000, 12000, 14000, 16000, 18000 and 20000 Hz in the same situation by the same audiologist. All subjects had normal immittance audiometry results with tympanometry. Acoustic stapes reflex (ASR) thresholds have measured in 500, 1000, 2000 and 4000 Hz.

Statistical Analysis

All data were analyzed using statistical analyses were performed with SPSS-15.0 software (SPSS Inc. IL, Chicago, USA). A *p*-value of less than 0.05 was regarded as significant. The normality of the data distribution was confirmed using the Kolmogorov-Smirnov test. According to the results obtained from the normality test or not, the statistical analysis of the pure tone audiometry, acoustic stapes reflex thresholds, P_aO_2 and spirometric results were performed with the Kruskal Wallis test or *t* test. Hearing threshold levels in PTA and hearing thresholds in ASR were analyzed with using Kruskal Wallis test in the patients' pulmonary function tests and P_aO_2 of arterial blood gases. Fisher's exact chi-squared test was used to compare categorical variables.

Table I. The demographic data of the groups.

	Group A	Group B	Group C
Median age (year)	37.41 ± 7.23	41.77 ± 7.14	40.33 ± 7.73
Male/Female (n)	9/12	10/11	10/12
FVC (%)	90.79 ± 28.41	82.46 ± 35.87	105.84 ± 13.13
FEV ₁ (%)	78.74 ± 25.47	70.69 ± 30.82	93.27 ± 5.91
FEV ₁ /FVC (%)	70.34 ± 22.15	65.48 ± 28.89	84.95 ± 5.44
pH	7.43 ± 0.01	7.42 ± 1.02	7.43 ± 0.91
PO ₂ (mmHg)	82.83 ± 7.60	66.5 ± 7.55	85.31 ± 6.10
PCO ₂ (mmHg)	34.87 ± 2.99	33.55 ± 4.01	35.72 ± 2.47
SaO ₂ (%)	95.66 ± 1.55	91.83 ± 3.67	96.45 ± 0.81
HCO ₃ (mEq/L)	22.62 ± 2.06	22.72 ± 4.77	23.63 ± 2.01

Data are given mean ± SD; Group A: Patients with PaO₂ > 75 mmHg; Group B: Hypoxic patients with PaO₂ ≤ 75 mmHg; Group C: Control group.

Results

There were 19 men and 23 women in the asthma group and the mean age was 39.28 years (23 to 51 years). The mean age of the control group was 40.33 years (18 to 50 years) (10 male and 12 female). There was no statistically significant difference in the median age and gender between the groups. It has been shown some baseline characteristic features of all groups in Table I.

The standard deviation and mean value of air and bone conduction hearing threshold levels for 500, 1000 and 2000 Hz speech discrimination scores could be seen in Table II. The results are in normal range for Group A and Group B. We could also see better mean value of air conduction hearing threshold levels in Group A (Figure 1). There was no significant correlation between the air and bone conduction hearing threshold levels and speech discrimination scores between the groups ($p > 0.05$).

Hearing threshold levels for group A, group B and group C were presented in the Figure 2 A and

B for right ears and in the Figure 3 A and B for left ears. All patients had normal peripheral hearing threshold levels across 250 Hz to 3000 Hz in the both ears. Significant differences were observed between the chronic asthma patients and control group for the extended high frequencies (10000-20000 Hz). Hypoxic asthma patients (group B) had statistically more significant increased hearing threshold levels than non-hypoxic asthma patients (group A) in frequencies higher than 10000 Hz ($p < 0.05$) (Figure 2 B, Figure 3 B).

All patients have normal tympanogram type A. The standard deviation and mean values of acoustic stapes reflex thresholds at 500, 1000, 2000 and 4000 Hz was presented in Table III. There was no significant correlation at the acoustic stapes reflex threshold levels the groups ($p > 0.05$). In addition, there was no significant correlation between pulmonary function tests and blood gas studies ($p > 0.05$). There were no statistical differences between the hearing threshold levels and FEV₁, FVC and FEV₁/FVC in the groups ($p > 0.05$).

Table II. The standard deviation and mean value of air and bone hearing threshold levels for 500, 1000 and 2000 Hz and discrimination scores were presented.

		Group A	Group B	Group C
AC HTL	Right ear	12.87 ± 5.19	19.27 ± 13.60	11.87 ± 5.29
	Left ear	9.25 ± 6.11	17.83 ± 11.74	9.24 ± 5.11
BC HTL	Right ear	9.25 ± 6.11	13.38 ± 7.96	8.34 ± 7.11
	Left ear	8.33 ± 5.17	12.94 ± 9.20	8.45 ± 4.15
SDS	Right ear	98.37 ± 3.66	93.66 ± 7.86	97.52 ± 4.57
	Left ear	97.62 ± 5.57	93.16 ± 8.36	98.61 ± 3.47

Data are given mean ± SD; Group A: Patients with PaO₂ > 75 mmHg, Group B: Hypoxic patients with PaO₂ ≤ 75 mmHg; Group C: Control group; ACHTL: Air conduction hearing threshold levels, BCHTL: Bone conduction hearing threshold levels, SDS: Speech discrimination scores.

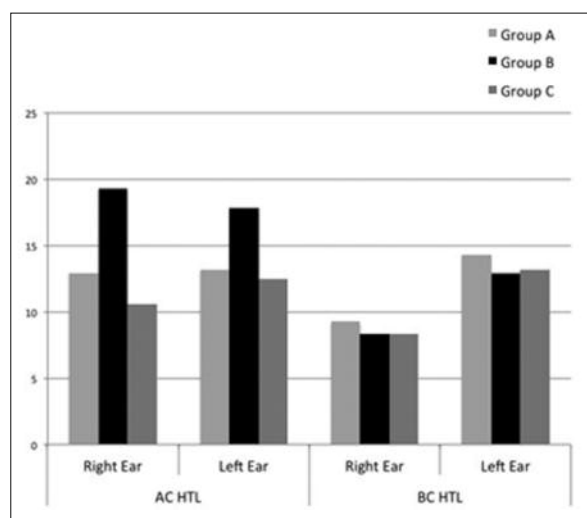


Figure 1. The mean value of air conduction hearing threshold levels for 1000, 2000 and 4000 Hz in Group A are better than in Group B. Vertical axis: Decibel (dB); horizontal axis: Frequency, herthz (Hz); Group A: Patients with $\text{PaO}_2 > 75$ mmHg; Group B: Hypoxic patients with $\text{PaO}_2 \leq 75$ mmHg; Group C: Control group; ACHTL: Air conduction hearing threshold levels; BCHTL: Bone conduction hearing threshold levels.

Discussion

A deterioration of the hypoxemic state in asthmatics was reported in the literature⁷. Asthmatic patients frequently have airway obstruction in a prolonged time. Bronchospasms cause a worsening of ventilation-perfusion and pulmonary vasoconstriction with decreasing pulmonary blood flow occurs. Arterial oxygen saturations may drop in severe clinic state⁷.

Diseases that cause hypoxia or ischemia, such as embolism and vascular disease, could also induce hearing loss⁵. The reduction of oxygen supply to the cochlea causes marked affection on the cochlear potential. The transduction mechanism of the inner ear is highly dependent upon the cochlear oxygen supply^{4,5}. There are only a few studies for studying auditory functions in chronic pulmonary diseases. Ibrahim et al⁵, found that children with chronic lung diseases were liable to cochlear dysfunction due to prolonged hypoxia. On the other hand, hearing loss was detected in immune-mediated diseases such as systemic lupus erythematosus⁸. In this disease, it has been postulated circulating immune complexes that, rather than vasculitis, are the cause of micro infarctions of the capillaries or arterioles in the temporal bone.

The present results have shown that hearing loss was common in chronic asthma patients. We have found normal hearing threshold levels between 250 Hz to 3000 Hz in hypoxic and non-hypoxic asthma patients. Hearing loss had been seen from 4000 Hz in some patients. Decreasing hearing threshold level was common in high frequencies (10000 Hz to 20000) in the asthma patients with hypoxia. All of them had type (A) tympanograms indicating normal middle ear pressure. The acoustic stapes reflex thresholds were similar in both groups (A and B).

Asthma is diagnosed based on clinical evaluation with measures of pulmonary function showing variable or reversible airways obstruction. The FEV_1/FVC ratio is normally greater than 75% to 80%, and possibly greater than 90% in

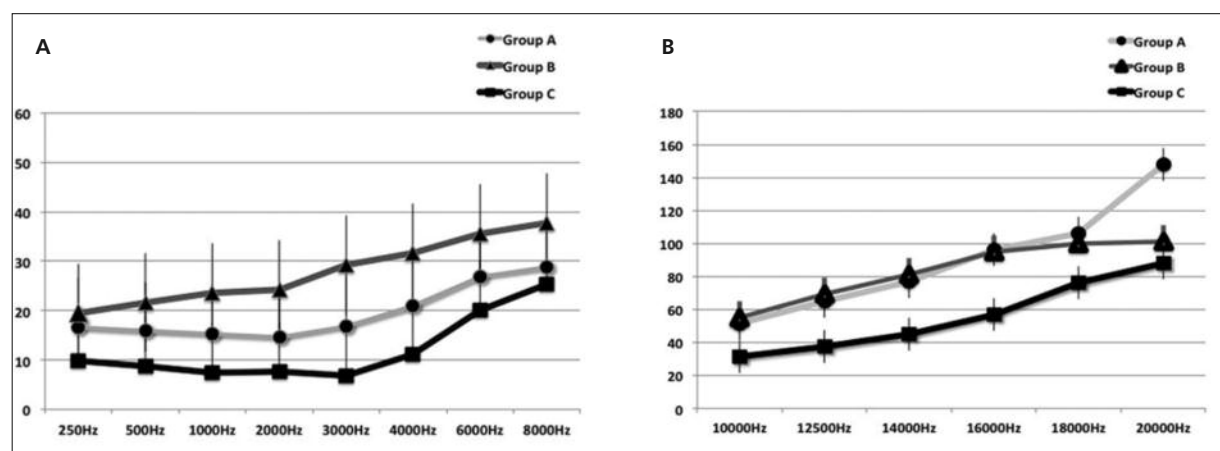


Figure 2. **A**, Hearing threshold levels in right ears with 250-8000 Hz frequencies. **B**, Hearing threshold levels in right ears with 10000-20000 Hz high frequencies. Vertical Axis: Decibel (dB); horizontal axis: Frequency, herthz (Hz); Group A: patients with $\text{PaO}_2 > 75$ mmHg; Group B: hypoxic patients with $\text{PaO}_2 \leq 75$ mmHg; Group C: Control group.

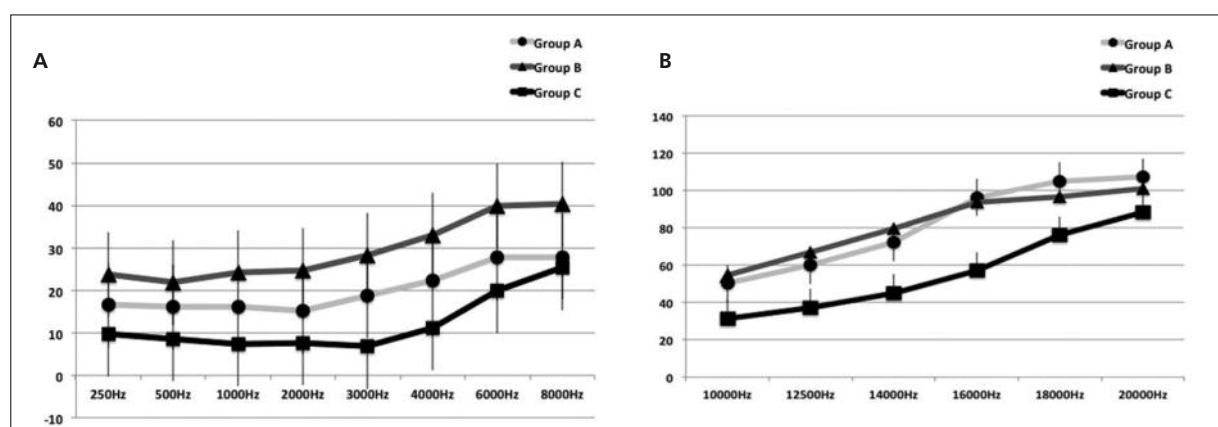


Figure 3. **A**, Hearing threshold levels in left ears with 250-8000 Hz frequencies. **B**, Hearing threshold levels in left ears with 10000-20000 Hz high frequencies. Vertical axis: Decibel (dB); horizontal axis: Frequency, herthz (Hz); Group A: Patients with $\text{PaO}_2 > 75 \text{ mmHg}$; Group B: Hypoxic patients with $\text{PaO}_2 \leq 75 \text{ mmHg}$; Group C: Control group.

children. In asthma, any values less than these suggest airflow obstruction¹. However, pulmonary function testing cannot be correlated with other measures of lung function in the literature^{9,10}. Also, there is no correlation between spirometric findings and arterial blood gases in patients with asthma. Asthma patients without symptoms and showing near normal spirometric finding may have meaningful gas exchange failures¹¹. In this study, we have already found that there was no significant correlation between pulmonary function tests and blood gas studies. In addition, there were no statistical differences between the hearing threshold levels and FEV_1 , FVC and FEV_1/FVC in all patients.

Systemic hypoxia decreases cerebral blood flow, and inadequate blood supply, or ischemia, in the cochlea is a contributor to hearing loss^{12,13}. Hypoxia causes a broad set of physical changes in the major cellular systems of the cochlea, changes that lead to permanent hearing threshold

shifts¹⁴. The basement of cochlea is more sensitive to damage. The basement of the cochlea is due to the high frequency area above 10000 Hz. Therefore high frequency audiometer is more useful to determine an early hearing loss. Routine pure-tone audiometric tests cover 125 Hz to 8000 Hz. Researchers have recently shown increased interest in the auditory sensitivity levels of the human organism for auditory signals, 8000 to 20 000 Hz. We have found hearing loss in high frequencies above 10000 Hz in asthma patients.

This is the first study for researching the auditory functions in patients with asthma in the literature. Atis et al¹⁵ have studied that the functions of the eighth cranial nerve and brainstem were highly impaired in severe chronic obstructive pulmonary diseases. Barbieri et al¹⁶ reported that there was no significant difference in eighth cranial nerve and brainstem in mild or moderate chronic respiratory insufficiency. Nakano et al¹⁷ investigated evoked potentials in patients with

Table III. The standard deviation and mean value of acoustic stapedius reflex threshold levels for 500, 1000, 2000 and 4000 Hz were presented.

		500 Hz	1000 Hz	2000 Hz	4000 Hz
Group A	Right ear	98.54 ± 9.94	96.25 ± 9.35	96.45 ± 12.46	105.41 ± 13.82
	Left ear	98.54 ± 11.17	95.41 ± 10.31	96.04 ± 12.33	105.62 ± 12.62
Group B	Right ear	93.88 ± 12.43	90.55 ± 8.89	91.94 ± 8.06	95.00 ± 11.37
	Left ear	92.77 ± 14.37	91.94 ± 9.41	90.83 ± 8.08	99.16 ± 12.03
Group C	Right ear	101.44 ± 8.93	99.35 ± 9.65	99.65 ± 11.46	109.57 ± 14.42
	Left ear	101.46 ± 12.17	98.41 ± 8.33	99.14 ± 13.43	110.63 ± 12.32

Data are given mean ± SD; Group A: Patients with $\text{PaO}_2 > 75 \text{ mmHg}$; Group B: Hypoxic patients with $\text{PaO}_2 \leq 75 \text{ mmHg}$. Group C: Control group.

chronic respiratory insufficiency, but did not find any significant differences in BAEP parameters between patients and controls.

Our study is not a large study group but it is the first study to find the auditory functions in chronic asthma. However, it would be unfair for us to perform a prospective study in a larger chronic asthma group. Another aspect of this study is the usage of subjective hearing test. If the objective hearing tests were used, it was better. Sensorineural hearing losses in high frequencies (10000 Hz-20000 Hz) are common in chronic asthma and are probably present more often than were formerly thought. Although this type of study can establish no cause and effect relationship, it appears that a relationship exists.

Conflict of Interest

The Authors declare that there are no conflicts of interest.

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