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Evaluation of middle ear and hearing status of ankylosing spondylitis patients with wideband tympanometry and pure tone audiometry tests

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Abstract

Objectives The aim of this study was to evaluate the middle and inner ear function and hearing status of Ankylosing spondylitis (AS) patients.

Methods One hundred twenty-four ears of 62 patients with AS and 90 ears (control group) of 45 healthy subjects were included in the study. The hearing levels of the participants were assessed with pure tone and high-frequency audiometry at the octave frequency between 250 and 16,000 Hz. The absorbance rates and resonance frequencies of middle ear were measured with the wideband tympanometry (WBT) test. AS group was divided into subgroups based on the disease activity, duration of follow-up, medications used for AS, and the subgroups were compared according to hearing status and absorbance and resonance frequencies of middle ears.

Results A statistically significant difference was found between the AS and control groups in terms of air and bone conduction thresholds at frequencies of 250, 500, 1000, 2000, and 4000 Hz and the mean PTA_1, PTA_2, and PTA_3 values ($p < 0.05$). In contrast, no statistically significant difference was observed between two groups in terms of high-frequency thresholds (8000–16,000 Hz). Although the middle ear resonance frequency obtained from the WBT test was higher in the AS group compared to the control group, no significant difference was observed ($p > 0.05$). The severity of disease adversely affected the hearing threshold at 250, and 500 Hz for air conduction, at 500 Hz for bone conduction threshold, and at PTA_1 ($p < 0.05$). The duration and severity of disease did not affect absorbance values of WBT ($p > 0.05$).

Conclusion To our knowledge, this is the first study to demonstrate the effects of AS patients on the middle ear function with WBT and to report middle ear absorbance values and resonance frequency changes in AS patients. The higher resonance frequency values found by WBT in AS patients may be due to the stiffness that develops as a result of middle ear involvement. According to pure tone and high-frequency audiometry findings, it has been seen that AS leads to SNHL especially at low frequencies.

Keywords Ankylosing spondylitis · Wideband tympanometry · Absorbance · Sensorineural hearing loss · Resonance frequency

Introduction

Ankylosing spondylitis (AS) is a chronic inflammatory disease that affects the axial skeleton, entheses, and, occasionally, peripheral joints. It is a member of the group of diseases called spondyloarthropathies. In addition to joint involvement, uveitis and cardiovascular and pulmonary involvements have also been associated with AS [1, 2].

Audiovestibular findings, especially sensorineural hearing loss (SNHL), may reportedly appear as a manifestation of AS [3–7]. Although the pathophysiological mechanism of SNHL occurring in AS patients has not been fully

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elucidated, current hypotheses suggest that it may be the result of granulomatous inflammation, vasculitis, or antibody formation. The change in high-frequency hearing loss and otoacoustic emission (OAE) responses compared to the control group suggests that outer hair cell destruction may be the cause of hearing loss [8, 9]. Since joints and joint connections are also involved, AS can affect the middle ear ossicular chain and connections and can consequently cause conductive hearing loss (CHL) [6, 10, 11]. There are studies reporting that the middle ear mechanism may also be affected, especially due to the stiffness that develops as a result of ossicular chain involvement [2, 4]. Although acoustic immittance tests using a 226 Hz probe tone have been performed to show middle ear involvement, to the best of our knowledge, there is no study in the literature evaluating middle ear functions with wideband tympanometry (WBT).

The hypothesis of this study was based on the fact that AS may adversely affect the middle and inner ear. The aim of the study was to investigate the middle and inner ear functions in age- and sex-matched AS patients and to prove the validity of our hypothesis by comparing the results with the control group.

Materials and methods

Ethical considerations

Ethical approval was obtained from Dokuz Eylül University Non-Invasive Research Ethics Committee (Protocol Number: 2017/12-09). All procedures were performed in accordance with the ethical standards of our institutional research committee and the 1964 Helsinki declaration. Informed consent was obtained from all participants.

Study design and setting

This research was performed as a cross-sectional, non-randomized case–control study in Dokuz Eylül University Faculty of Medicine, Department of Otorhinolaryngology and Rheumatology and Immunology, Izmir, Turkey.

Participants

Patients followed with diagnosis of AS in Dokuz Eylül University Rheumatology and Immunology Department formed the AS group. Patients who visited the Department of Otorhinolaryngology for any reason other than otological disorders, whose mean age and sex distribution were similar to the AS group, formed the control group.

Patients diagnosed according to the 1984 Modified New York diagnostic criteria were included in the AS group. Volunteering to participate in the study and not having otological, neurological, neoplastic, orthopedic, and other systemic diseases were determined as inclusion criteria. Both ears of the individuals participating in the study were examined under otomicroscopy and the tympanograms of both ears (GN Otometrics Company Madsen Zodiac Tympanometer, Assens, Denmark) appeared to be normal with a 226 Hz probe tone.

Patients with a systemic or chronic disease besides AS, ear disease, history of otological surgery, head trauma, hearing loss, or ototoxicity were excluded from the study.

The aim of the present study and the evaluation methods were explained to the participants who accepted to participate in the study and met the inclusion criteria. Written informed consent was obtained from each participant. Finally, 124 ears of 62 AS patients were included in the AS group, and 90 ears of 45 age matched healthy adults were included in the control group.

The AS group was divided into two sub-groups (active and remission groups) according to the Bath Ankylosing Spondylitis Disease Index (BASDAI), and four sub-groups according to the treatment received. These sub-groups were Non-Steroidal Anti-Inflammatory Drug (NSAID Group, $n=14$), Biological Agent (BA group, $n=8$), combination of drugs other than biological agents (OD group, $n=8$), and combination of biological agents and other drugs (BA + OD group, $n=32$). To investigate the effect of age on hearing, AS and control groups were divided into two sub-groups as participants over and under 45 years of age (AS < 45, AS ≥ 45, control < 45, and control ≥ 45).

Variables and data sources

Speech audiometry and pure tone audiometry evaluation was performed with a clinical audiometer (GN Otometrics Madsen Astera2, Taastrup, Denmark) using TDH 39 P earphones for air conduction, Sennheiser HD 300 earphones for high-frequency measurements, and B-71 bone vibrator for bone conduction measurements.

Pure tone audiometry was measured at the frequencies 250, 500, 1000, 2000, 4000, and 8000 Hz. High-frequency measurement was performed at 9000, 10,000, 12,500, 14,000, and 16,000 Hz. Bone conduction measurement was performed at 500, 1000, 2000, and 4000 Hz. The difference between bone (BC) and air conduction (AC) thresholds, the air–bone gap (ABG), was analyzed at 500, 1000, 2000, and 4000 Hz. The means of AC hearing thresholds at 500, 1000, and 2000 Hz; 1000, 2000, and 4000 Hz; and 500, 1000, 2000, and 4000 Hz were defined as PTA_1, PTA_2, and PTA_3, respectively.

Acoustic immittance measurements were performed with the GN Otometrics Company Madsen Zodiac (Assens, Denmark) device. WBT (Interacoustics Titan Suite, Wideband Tympanometry, Assens, Denmark) was performed

on both ears using a wideband click stimulus at a pressure range between + 200 and − 400 daPa. Absorbance values were recorded at 96 dB SPL in the frequency range of 226–8000 Hz under Ambient ($A_{ambient}$) and tympanometry peak pressure (A_{peak}) conditions. At each pressure value, absorbance values were measured at a total of 107 different frequencies between 226 and 8000 Hz. The results of the WBT were analyzed using MATLAB (version R2015b, The Math Works, Natick, MA, USA). Frequencies of 500, 1000, 2000, and 4000 Hz were used in statistical analyses.

Pure tone audiometry, high-frequency audiometry, acoustic immittance, and WBT measurements were performed by the only audiologist (SMD) involved in the study. The data were analyzed by blinded researchers (MAK, ED) and the analyses were cross-checked by another expert (PK) who was not among the authors of the study.

Statistical analysis

Statistical analyses were performed using the SPSS 15.0 package for Windows (SPSS Inc., Chigaco, Ilionis, USA) for statistical analyses. Data were evaluated using descriptive statistical methods and comparative tests. The numerical results were expressed as mean ± standard deviation, minimum, and maximum values, and the categorical variables were presented as percentages. Normality assumptions were evaluated via Levene's and Kolmogorov–Smirnov tests. Student's *t* test was used for comparison of variables between normally distributed groups, and Mann–Whitney *U* test was used to compare variables between non-normally distributed groups (for non-parametric data). Spearman's correlation test was used to evaluate the correlation between the variables considering that the groups were non-parametric data. *P* value of < 0.05 was accepted as statistically significant in all analyses.

Results

Participants and descriptive data

Demographic data and pure tone audiometry values of AS and control groups are given in Tables 1 and 2, respectively. No statistically significant difference was found between the AS and control groups in terms of age distribution ($p > 0.05$).

Outcome data and main results

All participants were showed normal (Type A) tympanogram pattern. No significant existed difference between the men and women in terms of audiological data within the AS and control groups ($p > 0.05$).

Table 1 Demographical characteristics of the participants

N (Number of ears)	AS group Mean ± SD (min–max) 124	Control group Mean ± SD (min–max) 90
Age (years)	46.6 ± 11.0 (20–69) < 45 years (*N* = 44) ≥ 45 years (*N* = 80))	43.8 ± 13.5 (20–76) < 45 years (*N* = 50) ≥ 45 years (*N* = 40))
Gender		
Male (*N*, %)	76 (61.3%)	38 (42.2%)
Female (*N*, %)	48 (38.7%)	52 (57.8%)
Medical treatment group		
NSAID (*N*, %)	28 (22%)	–
BA (*N*, %)	16 (13%)	–
OD (*N*, %)	16 (13%)	
BA + OD (*N*, %)	64 (52%)	–
Median follow-up time (years)	11.7 (1–40)	–
< 10 years (*N*)	58	
≥ 10 years (*N*)	66	
BASDAI Index		
Active (*N*)	20	–
Remission (*N*)	104	–
Erythrocyte sedimentation rate (mm/h)	17.2 (2–72)	–
CRP value (mg/L)	8.6 (0.3–55.0)	

NSAID nonsteroid anti-inflammatory drugs, *BA* biological agent, *OD* combination of drugs other than biological agents, *BA + OD* combination of biological agent and other drugs, *CRP* C-reactive protein, *BASDAI* Ankylosing Spondylitis Activity Index

Table 2 Pure tone audiometry thresholds and mean values, high-frequency audiometry thresholds and statistical analyses of AS and control groups

Frequency (Hz)	Hearing threshold (dB HL)		Statistical results
	AS group Mean ± SD (min–max)	Control group Mean ± SD (min–max)	*p* values
AC threshold			
250	10.9 ± 6.4 (0–30)	8.8 ± 5.6 (0–30)	***p* = 0.017***
500	9.8 ± 6.1 (0–30)	7.4 ± 6.2 (0–35)	***p* = 0.003***
1000	9.6 ± 6.6 (0–30)	6.6 ± 6.4 (0–25)	***p* = 0.001***
2000	11.8 ± 10.4 (0–45)	9.4 ± 9.7 (0–45)	***p* = 0.033***
4000	21.2 ± 18.1 (0–90)	16.6 ± 17.3 (0–70)	***p* = 0.016***
8000	22.8 ± 19.8 (0–90)	20.5 ± 20.1 (0–70)	$p > 0.05$
10,000	31.7 ± 24.7 (0–90)	28.9 ± 21.7 (0–70)	$p > 0.05$
12,500	45.5 ± 25.5 (0–80)	43.2 ± 26.1 (0–80)	$p > 0.05$
14,000	53.9 ± 20.7 (0–75)	50.8 ± 24.1 (0–75)	$p > 0.05$
16,000	49.2 ± 12.7 (0–65)	46.1 ± 15.2 (0–60)	$p > 0.05$
PTA_1	10.4 ± 6.9 (0–35)	7.8 ± 6.7 (0–30)	***p* = 0.001***
PTA_2	14.2 ± 6.9 (0–47)	10.9 ± 9.7 (0–47)	***p* = 0.005***
PTA_3	13.1 ± 8.7 (0–43)	9.9 ± 8.4 (0–40)	***p* = 0.002***
BC threshold			
500	8.6 ± 6.1 (0–25)	6.6 ± 6.2 (0–30)	***p* = 0.009***
1000	7.8 ± 6.5(0–30)	5.3 ± 5.8 (0–25)	***p* = 0.001***
2000	10.2 ± 9.9 (0–45)	7.8 ± 9.9 (0–45)	***p* = 0.013***
4000	17.0 ± 16.6 (0–80)	13.3 ± 16.0 (0–60)	***p* = 0.015***

AS ankylosing spondylitis, *PTA* pure tone audiometry average, *AC* air conduction, *BC* bone conduction, *dB HL* decibel hearing level, *Hz* hertz

*$p < 0.05$

A statistically significant difference was found between the AS and control groups in terms of air and bone conduction thresholds at frequencies of 250, 500, 1000, 2000, and 4000 Hz and the mean PTA_1, PTA_2, and PTA_3 values ($p < 0.05$). The thresholds were significantly higher in the AS group. In contrast, no statistically significant difference was observed between the two groups in terms of high-frequency thresholds (8000–16,000 Hz) (Table 2).

Although the middle ear resonance frequency obtained from the WBT test was higher in the AS group compared to the control group, no significant difference was observed ($p > 0.05$, Fig. 1).

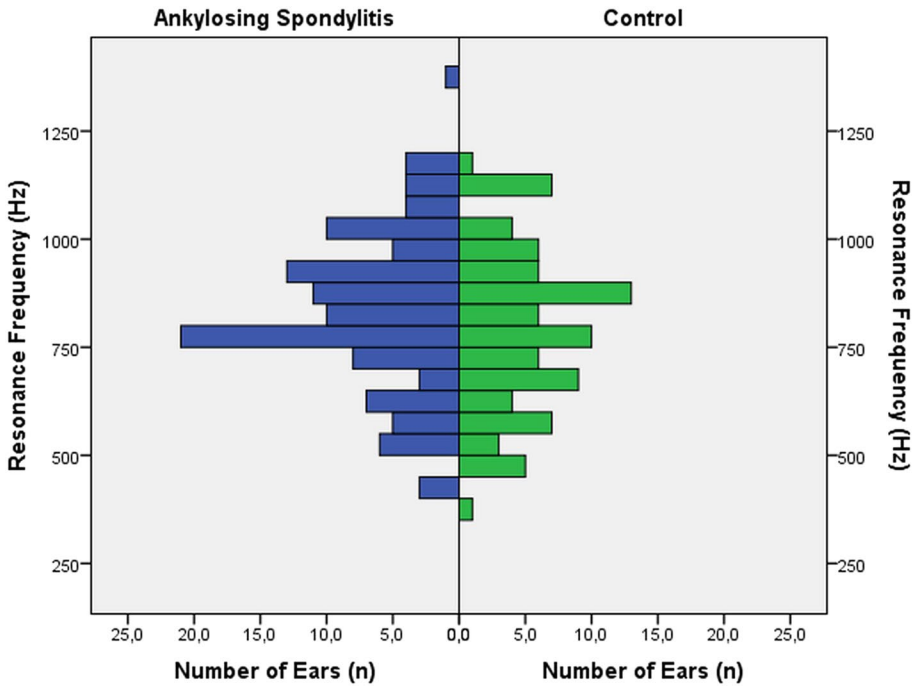


Fig. 1 Resonance frequency distribution of AS and control groups

The mean ambient and peak pressure absorbance values of WBT measurement showed no significant differences between groups ($p > 0.05$, Table 3, Fig. 2).

Table 3 Wideband tympanometry energy absorbance values (%) at octave frequencies

	AS group ($n = 115$)	Control group ($n = 88$)	p values
250 $A_{ambient}$	15.9 ± 10.7	16.0 ± 7.2	$p > 0.05$
500 $A_{ambient}$	27.2 ± 18.5	27.4 ± 15.2	$p > 0.05$
1000 $A_{ambient}$	57.2 ± 16.7	56.9 ± 17.1	$p > 0.05$
2000 $A_{ambient}$	65.9 ± 16.2	64.8 ± 13.2	$p > 0.05$
4000 $A_{ambient}$	43.4 ± 22.4	49.2 ± 18.9	$p > 0.05$
8000 $A_{ambient}$	27.4 ± 24.1	25.8 ± 20.3	$p > 0.05$
250 A_{peak}	17.3 ± 10.2	18.5 ± 7.5	$p > 0.05$
500 A_{peak}	30.5 ± 19.1	33.1 ± 15.8	$p > 0.05$
1000 A_{peak}	60.8 ± 15.9	62.8 ± 13.5	$p > 0.05$
2000 A_{peak}	65.0 ± 15.6	62.8 ± 13.9	$p > 0.05$
4000 A_{peak}	42.7 ± 22.1	47.7 ± 18.8	$p > 0.05$
8000 A_{peak}	27.1 ± 24.1	25.3 ± 20.4	$p > 0.05$

$A_{ambient}$ absorbance at ambient pressure, A_{peak} absorbance at peak pressure

The ambient and peak pressure of WBT absorbance values of the AS and control groups are shown on the frequency spectrum (Fig. 2).

AS group was sub-divided into four groups according to the drugs used and air and bone conduction hearing thresholds, WBT absorbance values and resonance frequency data were compared. No statistically significant difference was found between the sub-groups in terms of these data ($p > 0.05$). When the audiological data, resonance frequency, and absorbance values of active AS patients and AS patients in remission according to BASDAI index were compared, air conduction threshold of AS patients who were considered active were found to be higher at 250, 500, 1000, 2000, and 4000 Hz compared to those in remission. However, this difference was statistically significant only at 250 ($p = 0.03$), and 500 ($p = 0.004$) Hz for air conduction, at 500 Hz ($p = 0.02$) for bone conduction threshold, and at PTA_1 ($p = 0.02$) values in active AS patients than those in remission (Table 4). No statistically significant difference was found between resonance frequency and absorbance values between groups.

When the AS and control groups were sub-divided according to age and compared with each other, no significant difference or correlation was observed in audiological

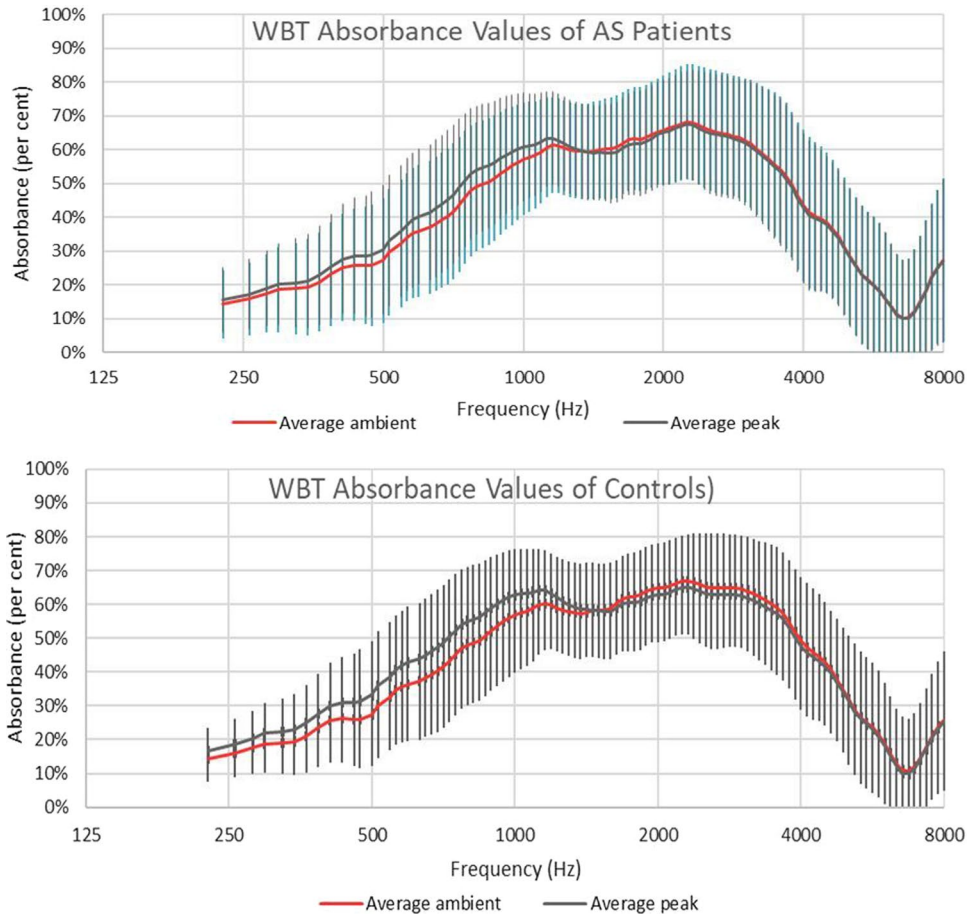


Fig. 2 Average middle ear energy absorbance values (percentage) at ambient and tympanometric peak pressure of the AS and the control group in the frequency spectrum

Table 4 Pure tone audiometry thresholds, averages, and high-frequency audiometry thresholds of AS sub-groups and statistical analyses

Frequency (Hz)	Hearing Threshold (dB HL) Mean ± SD							
	Active ($n=15$)	Remission ($n=100$)	< 10 year follow-up ($n=55$)	≥ 10 year follow-up ($n=60$)	NSAID ($n=27$)	BA ($n=14$)	OD ($n=14$)	BA + OD ($n=60$)
AC threshold								
250	**13.0 ± 5.2***	**10.5 ± 6.5***	10.6 ± 6.7	11.1 ± 6.1	11.1 ± 6.7	10.9 ± 6.1	8.4 ± 5.4	11.4 ± 6.5
500	**13.3 ± 6.3***	**9.1 ± 5.9***	9.1 ± 6.6	10.4 ± 5.7	8.2 ± 5.8	9.4 ± 5.1	9.7 ± 5.9	10.5 ± 6.6
1000	11.5 ± 7.6	9.2 ± 6.4	9.2 ± 6.7	9.8 ± 6.6	9.5 ± 5.7	8.1 ± 4.0	8.8 ± 7.6	10.2 ± 7.3
2000	16.8 ± 13.3	10.8 ± 9.5	11.5 ± 10.9	12.0 ± 10.0	11.3 ± 12.0	7.2 ± 3.6	10.3 ± 8.1	13.5 ± 11.0
4000	26.0 ± 19.3	20.2 ± 9.5	20.9 ± 18.7	21.4 ± 17.6	19.1 ± 15.9	13.8 ± 6.7	21.9 ± 15.7	23.8 ± 20.9
8000	20.3 ± 18.5	23.3 ± 19.9	21.4 ± 18.6	24.0 ± 20.7	17.1 ± 14.7	18.1 ± 14.6	22.8 ± 17.6	26.4 ± 22.5
10,000	21.8 ± 20.7	33.6 ± 25.0	30.7 ± 24.7	33.3 ± 24.1	27.7 ± 21.8	20.9 ± 18.6	29.7 ± 24.7	37.3 ± 25.6
12,500	37.5 ± 25.6	47.0 ± 25.3	44.1 ± 25.5	47.0 ± 25.1	42.9 ± 19.9	34.4 ± 22.8	44.7 ± 30.9	49.9 ± 25.8
14,000	47.5 ± 20.1	55.2 ± 20.7	52.3 ± 21.7	55.4 ± 19.9	52.9 ± 17.7	47.5 ± 24.0	48.8 ± 29.9	57.3 ± 18.0
16,000	51.0 ± 5.9	49.0 ± 12.7	48.1 ± 13.5	50.5 ± 10.1	51.4 ± 5.9	45.6 ± 16.1	41.9 ± 22.1	51.3 ± 7.7
PTA_1	**13.8 ± 8.1***	**9.7 ± 6.5***	7.7 ± 6.2	9.4 ± 5.9	9.6 ± 6.9	8.2 ± 3.6	9.6 ± 6.8	11.4 ± 7.5
PTA_2	18.1 ± 12.5	13.4 ± 9.6	7.2 ± 6.8	8.3 ± 6.2	13.3 ± 10.2	9.7 ± 3.8	13.6 ± 8.6	15.8 ± 11.4
PTA_3	14.6 ± 10.1	10.2 ± 7.5	9.4 ± 10.6	10.8 ± 9.2	9.7 ± 8.2	8.5 ± 3.2	10.8 ± 6.5	12.0 ± 9.2
BC Threshold								
500	**11.5 ± 6.9***	**8.0 ± 5.8***	16.8 ± 17.6	17.1 ± 15.8	7.0 ± 6.1	9.1 ± 5.5	9.1 ± 4.9	9.1 ± 6.5
1000	10.0 ± 6.7	7.4 ± 6.3	9.9 ± 7.4	10.8 ± 6.5	7.3 ± 5.9	7.5 ± 3.7	6.9 ± 5.4	8.3 ± 7.5
2000	15.3 ± 11.9	9.2 ± 9.2	13.9 ± 10.4	14.4 ± 10.1	9.3 ± 12.1	7.2 ± 3.6	9.4 ± 6.8	11.5 ± 10.5
4000	21.5 ± 19.3	16.1 ± 15.9	10.3 ± 8.6	11.4 ± 7.7	15.4 ± 14.6	10.3 ± 5.0	17.8 ± 12.9	19.1 ± 19.6

PTA pure tone audiometry average, *AC* air conduction, *BC* bone conduction, *dB HL* decibel hearing level, *Hz* hertz, *NSAID* nonsteroid anti-inflammatory drugs, *BA* biological agent, *OD* combination of drugs other than biological agents, *BA + OD* combination of biological agent and other drugs, *CRP* C-reactive protein, *BASDAI* Ankylosing Spondylitis Activity Index

*$p < 0.05$

threshold values, resonance frequency, and absorbance values between individuals under 45 years of age and those over 45 years of age ($p > 0.05$).

No significant relationship was observed between C-reactive protein levels, sedimentation values, hearing thresholds, WBT values, RF and absorbance rates of the AS group ($p > 0.05$).

The resonance frequency and WBT absorbance values of the AS and control groups are given in Table 5.

Table 5 Mean resonance frequency, WBT absorbance values of patients with ankylosing spondylitis and the control group

	Resonance frequency (Hz) median ± SD (min–max)	Absorbance values median ± SD (%)	*p*
AS ($n=115$)	832 ± 184 (403–1371)	45.6 ± 7.8	$p > 0.05$
Control ($n=88$)	794 ± 186 (395–1174)	46.9 ± 7.7	
Active ($n=15$)	848 ± 124 (643–1029)	47.7 ± 7.6	$p > 0.05$
Remission ($n=100$)	830 ± 190 (403–1371)	45.3 ± 7.9	
< 10 year follow-up ($n=55$)	811 ± 191 (403–1185)	45.9 ± 7.6	$p > 0.05$
≥ 10 year follow-up ($n=60$)	851 ± 174 (511–1371)	45.3 ± 8.1	
NSAID ($n=27$)	840 ± 153 (527–1174)	45.8 ± 8.5	$p > 0.05$
BA ($n=14$)	878 ± 250 (441–1371)	47.3 ± 8.4	
OD ($n=14$)	820 ± 202 (403–1139)	44.6 ± 8.7	
BA + OD ($n=60$)	821 ± 175 (440–1185)	45.4 ± 7.3	

AS ankylosing spondylitis, *NSAID* nonsteroid anti-inflammatory drugs, *BA* biological agent, *OD* combination of drugs other than biological agents, *BA + OD* combination of biological agent and other drugs

When we compared the pure tone audiometry thresholds, resonance frequency, and WBT data of AS patients followed for ≥ 10 years and those followed for < 10 years, no significant difference or correlation was observed ($p > 0.05$).

Discussion

AS is a chronic, inflammatory rheumatologic disease of unknown origin, which belongs to the group of spondyloarthropathies, and it particularly affects the sacroiliac joints [12]. Irregular erosion and sclerosis are observed in the affected joints. Subchondral tissues show granulomatous changes and are infiltrated by plasma cells, lymphocytes, mast cells, macrophages, and chondrocytes. Normal tissue is replaced by fibro-cartilage tissue and ossifies in the following periods [13].

The relationship identified between various autoimmune diseases and SNHL led to the hypothesis that AS may also show audiovestibular involvement, and studies have been conducted on this subject [14].

Hearing loss in AS was first reported by Magaro et al. in a case report and defined as CHL [15]. Although it was initially emphasized that AS is associated with hearing loss in the form of CHL, subsequent studies showed that AS involvement does not occur in the form of CHL, but rather occurs in the form of SNHL, which is seen at high frequencies [2–5, 10, 16, 17]. Contrary to the literature, in their study investigating hearing loss in AS patients, Ajmani S et al. observed low-frequency CHL [6]. Although Camilleri et al. [18] stated that the prevalence of chronic otitis media is high in AS patients, many researchers reported that AS patients do not have any middle ear problems and have SNHL [5, 8, 9, 11, 16, 17, 19]. In their study with 45 AS patients and 31 healthy volunteers, Adam et al. stated that the high-frequency hearing loss they encountered could be evaluated as an extra-articular involvement of AS [2]. In the present study, CHL was not observed in pure tone audiometry in the AS and control groups, consistent with the literature, and all patients with hearing loss had SNHL.

Although the hearing thresholds were higher in the AS group than in the control group at all frequencies measured, a significant difference was observed only in the 250–4000 Hz range. Dağlı et al. reported that the hearing thresholds of the AS group were significantly higher at all frequencies compared to the control group [9]. After the histological demonstration showing the development of hydrops in autoimmune inner ear diseases and its association with other rheumatological and autoimmune diseases, immune complex-mediated mechanisms have surpassed other theories explaining the development of SNHL [20]. Detection of low tone hearing loss in the present study suggests that autoimmune processes are more prominent in the pathogenesis. It can be argued that subclinical endolymphatic hydrops developing as a result of autoimmunity may be responsible for hearing loss. However, it would not be prudent to explain this hearing loss with a single mechanism or to attribute it to a single cause.

Although Adam et al. [2] stated that hearing loss is associated with the patient's age, sex, and disease duration, no statistically significant difference or correlation was found in the present study between AS patients with a disease duration of ≥ 10 years and those with a disease duration of < 10 years in terms of audiological data. Adam et al. mentioned studies indicating that drugs used in the treatment of AS may have an ototoxic effect [2]. Savastano et al. emphasized that sulfasalazine (SASP) treatment caused cochlear loss and recovery occurred with discontinuation of treatment [21]. Ajmani et al. [6] and Casellini et al. [3] found no association between NSAID treatment and hearing loss. Even if a relationship is found between the treatments received by patients during the study period and hearing loss, it is not possible to make a definitive judgment as to whether this hearing loss is due to the treatment received. To compare drug groups, further studies with more homogeneous groups comparing hearing levels between AS patients receiving treatment with a single drug group and healthy controls are needed.

Although some authors [3, 6, 22] could not reveal a clear relationship between active AS patients and hearing loss, others [2, 23] stated that there may be a relationship between AS activity and hearing loss. In the present study, when active AS patients and those in remission were compared, the hearing thresholds of active patients compared to those in remission were worse at thick frequencies. This worsening of hearing thresholds seen in active patients suggests that there may be a relationship between the anti-inflammatory process in AS and hearing loss.

Since AS causes limitation of movement in the sacroiliac joint, and leads to fibrosis, ossification, and interosseous bridging in later stages, and characteristically creates a picture of enthesitis, it can be predicted that in case of middle ear involvement, such involvement will increase the stiffness of the middle ear. Due to the effect of increased stiffness, it can be expected that the middle ear RF value to be obtained from AS patients will shift to higher frequencies compared to normal patients [24–26]. In the present study, the RF value of the AS group (832 ± 184 Hz) was higher than the control group (794 ± 186 Hz) as expected, but the difference was not statistically significant. Furthermore, the RF value was also higher in active patients compared to those in remission and in patients with disease duration of > 10 years compared to those with a disease duration of < 10 years; however, the difference was not significant. Similarly, the RF values of active AS patients and patients with a disease duration of ≥ 10 years were non-significantly higher than those of the control group.

The presence of AS, disease activity, and disease duration were thought to not have a significant effect on RF.

Many published studies have shown that middle ear wideband absorbance rates are highest in the range of 1000–4000 Hz, and absorbance rates decrease at frequencies above or below this range [26, 27]. The absorbance curves obtained in the present study show that absorbance increases slowly from 250 Hz up, this increase continues up to the 1000 Hz level, fluctuates between 1000 and 4000 Hz, and then decreases rapidly after 4000 Hz (Fig. 2). This configuration is consistent with other results in the literature [26, 27].

Conclusion

The results of the present study indicated that disease activity had no effect on absorbance rates. To the best of our knowledge, there is no study on this subject conducted with AS patients. In this regard, the results are important as this is the first study to report middle ear absorbance values and resonance frequency changes in AS patients.

Owing to the predisposition to enthesis in the ligaments and ankylosis in the joints AS affects, it can be argued that AS will have a tendency to increase the stiffness effect in the case of middle ear involvement. In support of this view, the middle ear RF value was found to be higher than the control group; however, the difference was not statistically significant. Therefore, these results should be supported by further research on large series of AS patients with wideband immittance measurements.

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Declarations

Conflict of interest The authors declare no conflict of interest or competing financial interests.

Ethical approval This prospective non-randomized case–control clinical research was approved by Dokuz Eylul University, Ethical Committee (protocol number: 2017/12-09).

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