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ORIGINAL ARTICLE

Hearing loss in patients with extracranial complications of chronic otitis media

Authors' Contribution:
A – Study Design
B – Data Collection
C – Statistical Analysis
D – Data Interpretation
E – Manuscript Preparation
F – Literature Search
G – Funds Collection

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ABSTRACT:

Objective: A pure tone audiomety analysis of patients with extracranial complications of chronic suppurative otitis media (ECCSOM).

Material and methods: We retrospectively analyzed audiometric data performed before treatment from 63 patients with ECCSOM (56 single, 7 multiple complications) including groups of frequencies.

Results: The greatest levels of hearing loss were noted for 6 and 8 kHz (79.0 and 75.7 dBHL) and for the frequency groups high tone average (76.1 dBHL). As regards the severity of hearing impairment in pure tone average the prevalence of complications was as follows: labyrinthitis (77.8±33.6 dBHL), facial palsy (57.1±14.3 dBHL), perilymphatic fistula (53.9±19.9 dBHL) and mastoiditis (42.2±9.5 dBHL) (p=0.023).

Conclusions: Hearing loss in ECCSOM is dominated by mixed, high-tone, moderate type of hearing loss, most profound in labyrinthitis. In 11% of patients the complication causes total deafness.

KEYWORDS: chronic suppurative otitis media, complications extracranial, hearing loss

INTRODUCTION

Chronic suppurative otitis media (CSOM) is a destructive disease of the ear. Characteristic signs and symptoms of this disease include lesions of the tympanic membrane, discharge from the ear, erosion of the ossicles and bony walls of tympanic cavity, and hearing loss. In simple CSOM, we commonly observe conductive hearing loss, and the disease usually has a benign course without complications. CSOM due to cholesteatoma and granulations has a different clinical course, and we typically observe mixed hearing loss of various degrees. Complications of CSOM are caused primarily by cholesteatomas, and have been divided into extracranial and intracranial. The former group comprises labyrinthitis, perilymphatic fistula, facial nerve palsy, acute mastoiditis, Bezold abscess, and petrositis. Intracranial complications include meningitis, epidural abscesses and extradural empyema, cerebral abscesses, cavernous sinus thrombophlebitis, and otitic hydrocephalus [1-3]. It is estimated that extracranial complications are at least twice more frequent than intracranial complications. Extracranial complications of chronic suppurative otitis media (ECCSOM) usually lead to hearing loss and even total deafness of the affected ear. In acute mastoiditis, an increasing discharge from the ear and mixed or conductive hearing loss can be observed [4-5]. Labyrinthitis is associated with slowly progressive high-frequency sensorineural hearing loss or mixed hearing loss. Unfavorable outcomes of purulent labyrinthitis include total deafness and vestibular paresis or paralysis [2, 6]. In CSOM, perilymphatic fistulas are mainly formed in the lateral semicircular canal in spite of its protrusion to the tympanic cavity and relatively easy penetration of cholesteatoma to the perilymphatic space in this location [7]. If this occurs, vestibular symptoms are dominant along with the Tullio phenomenon (sound-induced episodic vertigo and disequilibrium) and sensorineural hearing loss [8-10]. Facial palsy is most commonly associated with progressive mixed hearing loss [10]. It is due to an involvement of the posterior recessi of the tympanic cavity, especially the facial recess and the tympanic sinus. Petrositis is associated with copious purulent discharge from the ear, progression of the conductive component of hearing loss, irritation of the Gasser's ganglion (trigeminal ganglion), or even involvement of the Dorello canal (cranial nerve VI) with signs of Gradenigo syndrome. However, currently this complication is rarely found [11-12]. The aim of the study was to quantitatively and qualitatively evaluate hearing in patients with ECCSOM and to compare

the severity of hearing impairment between patients with particular types of extracranial complications.

MATERIALS AND METHODS

Patients

During a 14-year period, from 1 January 2000 to 1 March 2013, 99 patients with extracranial and intracranial complications of chronic suppurative otitis media (ICCSOM) were identified among 1574 patients with CSOM using the International Classification of Diseases, 10th Revision (ICD-10); codes: H.66.1-H.66.3. The group comprised 91 patients with ECCSOM and 8 with ICCSOM. Out of 91 consecutive patients with ECCSOM, we excluded 10 patients who had 2 or more combined complications (ECCSOM and ICCSOM). The main exclusion criteria included an intracranial complication, complication of acute suppurative otitis media, lack of pure tone audiometry results, hearing test not consistent with the accepted criteria (see: Methods), primary pure tone audiometry performed during or after treatment, congenital hearing loss, and post-traumatic hearing loss. The final group of patients consisted of 63, out of 81 subjects with ECCSOM, for whom retrospective audiometric data were obtained. The data of these patients were reviewed including clinical symptoms and examination findings, high-resolution contrast-enhanced computed tomography (CT), contrast-enhanced magnetic resonance imaging (MRI), surgery reports, and intraoperative findings. Patients with ECCSOM were classified to have labyrinthitis, perilymphatic fistula, acute mastoiditis, facial nerve palsy, or petrositis, as previously described [1-10].

METHODS

Pure tone audiograms were performed in a soundproof booth (ISO 8253, ISO 8253). Signals were generated by calibrated clinical audiometers Itera II and Midimate 622, manufactured by Madsen Electronics (Otometrics, Copenhagen, Denmark) (PN-EN 60645-1, ISO 389, ISO 8789, ISO 7566, ISO 8798). The equipment employed corrections for standard hearing level ANSI S 3.6-1989 and 2004. American Speech-Language-Hearing Association guidelines for Pure-Tone Threshold Audiometry were used to test subjects in the study [13]. For air conduction testing, the electrical signal generated by the audiometer was coupled with TDH-39P headphones. For bone conduction testing, the audiometer was coupled with a Radioear B-71 bone-conduction vibrator (New Eagle, PA). If the examined person did not respond to the signal pitch at any level, a 120 dBHL level was used for further calculations. We retrospectively assessed audiometric data of patients with ECCSOM. All audiograms were performed before treatment of complications. We analyzed hearing loss at single frequencies and groups of frequencies: PTA (0.5, 1, 2 kHz), HTA (4, 6, 8 kHz), OAA (0.5, 1, 2, 4, 6, 8 kHz), and PMTA (0.5, 1, 2, 4 kHz). The air-bone gap was measured for all tested frequencies and groups of frequencies. All obtained thresholds were averaged according to type of ECCSOM. The values of hearing thresholds were comparable between single and multiple complications for air- and bone-conduction and the air-bone gap. Conductive hearing loss was defined as the air-bone gap ≥15 dBHL in all tested frequencies and bone conduction curve ≤20 dBHL. Sensorineural hearing loss was defined as the air-bone gap <15 dBHL in all tested frequencies and bone conduction curve >20 dBHL. The remaining audiograms were classified as mixed hearing loss. When there was no response to signals up to 120 dBHL, total deafness was recognized. The averaged hearing thresholds for these types of hearing loss were compared and statistically analyzed.

STATISTICS

Statistical analysis was carried out using the Mann-Whithey U-test for independent groups and the Kruskal-Wallis test. $P<0.05$ was considered as significant. Statistical analysis was performed using STATISTICA, version 7.1 (StatSoft, Inc., 2005).

RESULTS AND ANALYSIS

Patients with ECCSOM were aged between 6 years and 84 years (mean age of 50.7±17.8 years). Among patients treated surgically (53 cases), there were 46 cases of cholesteatomal CSOM and 7 cases of granulomatous CSOM. Among 63 subjects, 70 complications of ECCSOM were found (56 patients with single and 7 patients with multiple complications). Among patients with ECCOM, surgical treatment was most common (53/63), 9 patients were treated conservatively, and 1 patient was not treated at all due to lack of consent. The remaining demographic and clinical data, including distribution of ECCSOM, are presented in Table 1. Pure tone audiometry parameters of all included patients were averaged and are presented in Table 2. The highest hearing thresholds for air conduction were obtained for 6 kHz and 8 kHz (79.0±28.6 and 75.7±32.6 dBHL, respectively). Hearing loss in low tones was lower than or equal to 60 dBHL. Bone conduction had the highest values for 6 kHz and 4 kHz (66.4±33.6 and 59.1±33.1 dBHL, respectively). The air-bone gap had the highest value for 1 kHz and 0.75 kHz, decreasing in high frequencies. Higher thresholds were noted on high tone average (HTA), 76.1±29.0 dBHL, than on pure tone average (PTA), 60 dBHL. (Table 2)

All threshold values in patients with multiple complications were higher than in patients with single complications, except for the

Tab. I. Characteristics of patients with ECCSOM (n=63).

	N	%
Male	35	55,6
Female	28	44,4
Mean age (SD)	50,7 (17,8)	
Right-sided lesion	33	52,4
Right-sided lesion	30	47,6
TYPE OF CSOM		
cholesteatoma	51	81,0
granulation	12	19,0
TYPE OF ECCSOM	**ALL (SINGLE)**	
perilymphatic fistula	34 (29)	54,0 (51,8)
labyrinthitis	18 (16)	28,5(286)
facial palsy	14 (8)	22,2 (14,3)
mastoiditis	3 (3)	4,7 (5,3)
petrositis	1 (0)	1,6 (0,0)
single	56	88,9
multiple	7	11,1

Tab. II. Hearing thresholds at single frequencies and groups of frequencies on pure-tone audiometry for patients with ECCSOM (n=63).

SINGLE FREQUENCY/ GROUP OF FREQUENCIES (KHZ)	AIR CONDUCTION (DBHL)	BONE CONDUCTION (DBHL)	AIR-BONE GAP (DBHL)
0,125	60,1±26,6	-	-
0,25	59,2±27,0	36,7±33,8	22,6±13,1
0,5	59,8±26,4	37,5±31,7	22,3±11,7
0,75	61,0±26,0	37,0±31,7	24,0±11,7
1	62,5±26,8	38,4±32,5	24,1±12,3
1,5	64,8±26,9	42,9±31,4	21,9±12,1
2	62,1±27,3	45,8±31,6	16,3±10,9
3	68,2±29,7	5,3±34,1	15,9±10,7
4	73,7±28,8	59,1±33,1	14,5±9,4
6	79,0±28,6	66,4±33,6	12,5±10,7
8	75,7±32,6	-	-
0,5–1–2 (PTA)	61,5±26,3	40,6±31,5	20,9±10,6
4–6–8 (HTA)	76,1±29,0	-	-
0,5–1–2–4 (PMTA)	64,5±25,9	-	-
0,5–1–2–4–6–8 (OAA)	68,8±26,0	-	-

air-bone gap at 1-2 kHz; however, the differences were not statistically significant (Table 3). The mean PTA value for complications caused by cholesteatomal CSOM was 64.2±27.7 dBHL, and was higher than that for complications of granulomatous CSOM (49.9±14.9) (p=0.018).

The most prevalent types of hearing loss in patients with ECCSOM were mixed hearing loss (32 patients; 50.8%) and conductive hearing loss (20 patients; 31.7%). In 7 patients, complete deafness of the affected ear was diagnosed. Sensorineural hearing loss was least common (4 patients; 6.3%). In patients with single complications, the percentage distribution of particular types of hearing loss was similar, while in patients with multiple complications there were no cases of clear conductive hearing loss, and mixed hearing loss was dominant (5 of 7; 71.4%). These relations are illustrated in Fig. 1. Differences between the groups were not statistically significant (p=0.175).

We compared mean hearing thresholds for average frequencies of air conduction in patients with single complications. In this way, we created a gradation of hearing loss severity according to the type of complication. The worst hearing thresholds, significantly worse than in the case of other complications, were found for labyrinthitis (range 74.1±35.4 dBHL for 0.125 kHz - 90.6±29.1 dBHL for 6.0 kHz, PTA AC - 77.8±33.6 dBHL),

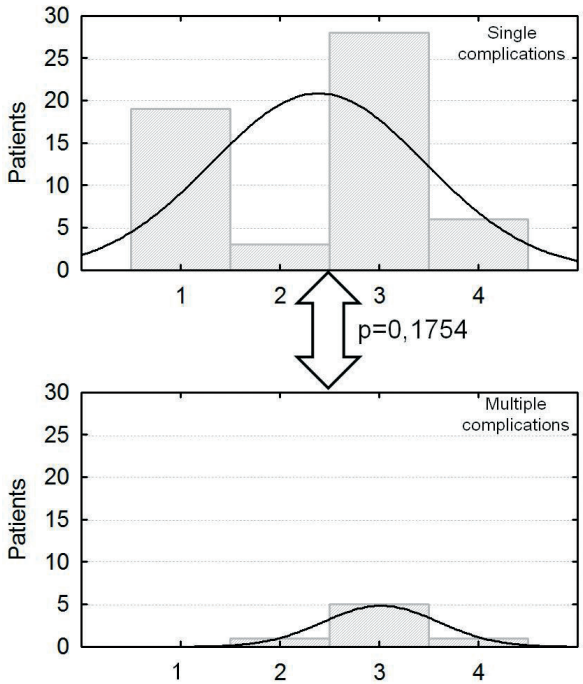

Fig. 1. Histograms of hearing loss types (1 – conductive hearing loss, 2 – sensorineural hearing loss, 3 – mixed hearing loss, 4 – total deafness) on tonal audiometry for patients with single and multiple ECCSOM.

followed by facial nerve paralysis (range 47.5±11.0 dBHL for 0.125Hz - 87.5±24.1 dBHL for 6.0 kHz, PTA AC - 57.1±14.3 dBHL) and perilymphatic fistula (range 52.8±18.8 dBHL for 0.25 kHz - 73.3±32.7 dBHL for 8.0 kHz, PTA AC - 53.9±19.9 dBHL). The lowest hearing thresholds were found for mastoiditis (range 35.0±8.7 dB for 0.125 and 0.75 kHz - 58.3±27.5 dBHL for 4.0 kHz, PTA AC - 42.2±9.5 dBHL). Differences between complications for PTA AC were statistically significant (p=0.023). (Fig. 2)

Among patients with single complications, we compared hearing threshold differences of air conduction for single frequencies on pure tone audiometry. Statistically significant differences were found for the following frequencies: 0.125 (p=0.023), 0.25 (p=0.041), 0.5 (p=0.025), 0.75 (p=0.028) and 3.0 (p=0.037), and for the HTA and (p<0.0001) and PTA groups mentioned above (p=0.023). (Fig. 3, 4)

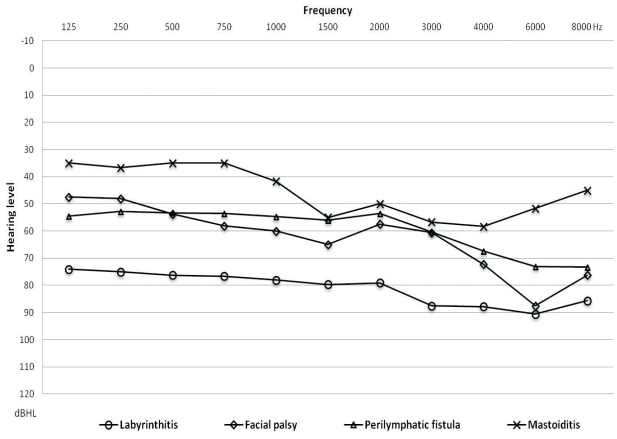

Fig. 2. Hearing thresholds on tonal audiometry for patients with ECCSOM (single complications).

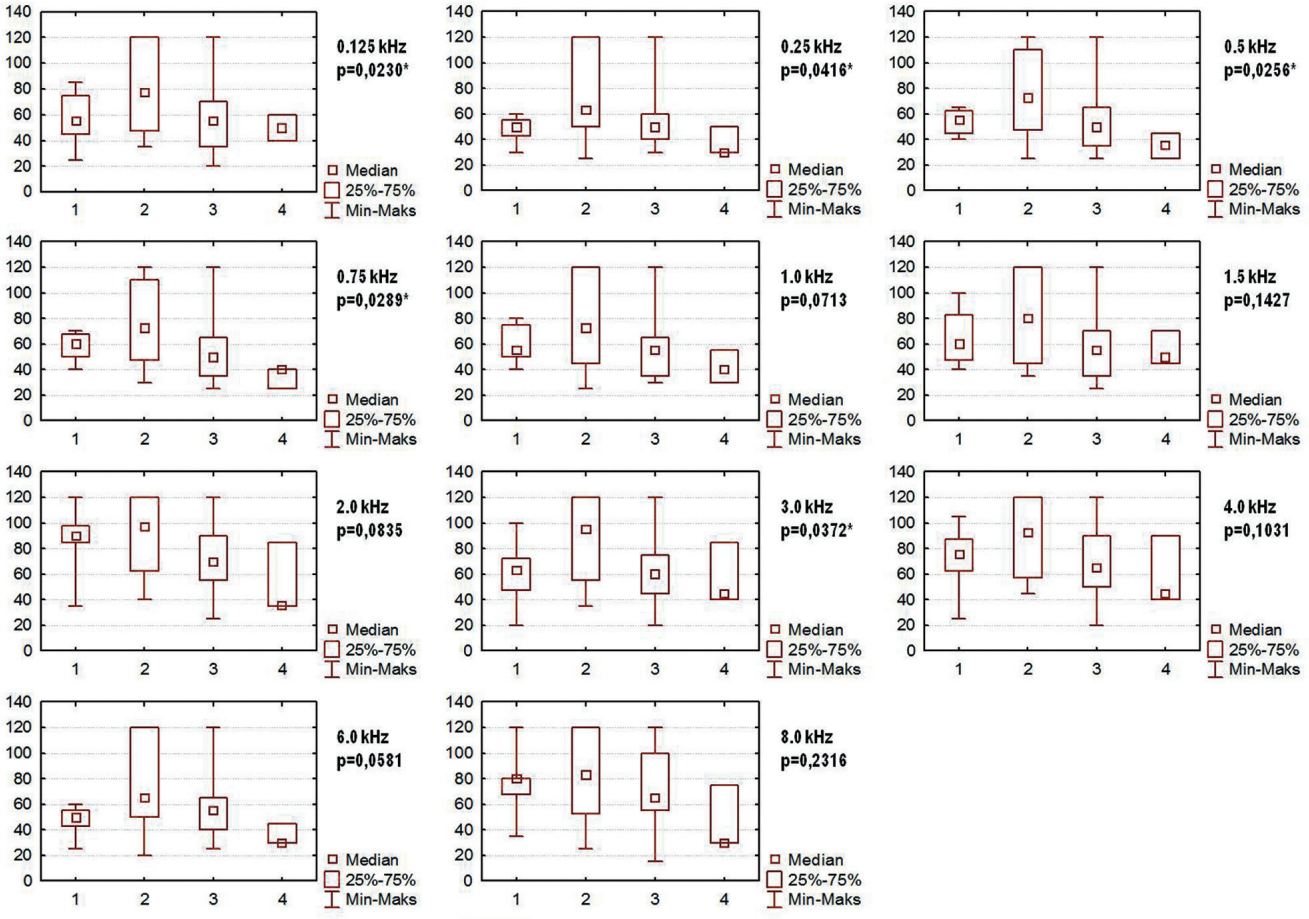

Fig.3. Statistical significance of differences in hearing thresholds for air conduction on tonal audiometry for single frequencies between patients with different ECCSOM - 1. perilymphatic fistula (n=29) vs. 2. labyrinthitis (n=16) vs. 3. facial palsy (n=8) vs. 4. acute mastoiditis (n=3).

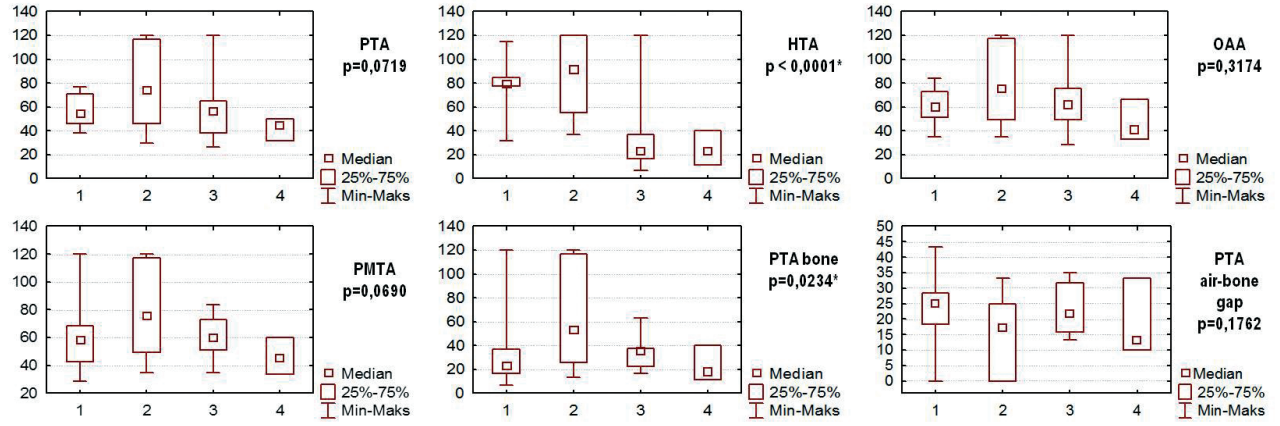

Fig. 4. Statistical significance of differences in hearing thresholds for air conduction on tonal audiometry for groups of frequencies for patients with different ECCSOM - 1. perilymphatic fistula (n=29) vs. 2. labyrinthitis (n=16) vs. 3. facial palsy (n=8) vs. 4. acute mastoiditis (n=3).

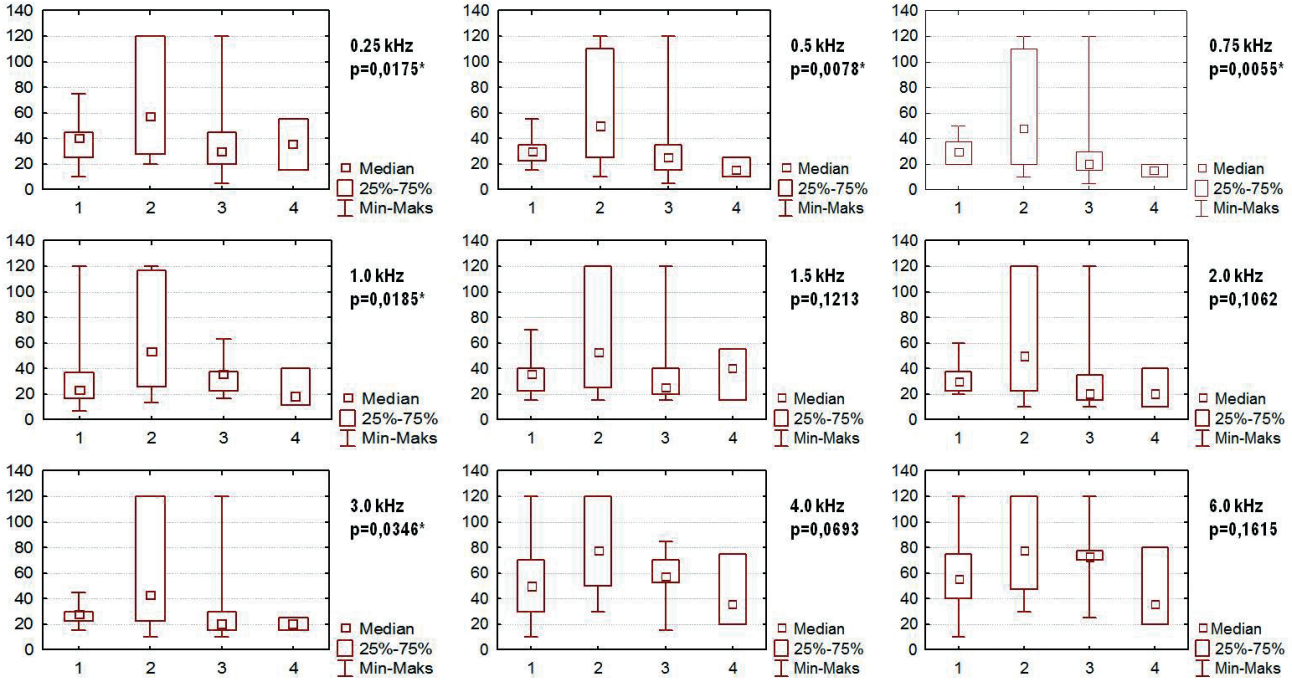

Fig. 5. Statistical significance of differences in hearing thresholds for bone conduction on tonal audiometry for single frequencies for patients with different ECCSOM - 1. perilymphatic fistula (n=29) vs. 2. labyrinthitis (n=16) vs. 3. facial palsy (n=8) vs. 4. acute mastoiditis (n=3).

Subsequently, we compared hearing threshold differences of bone conduction on pure tone audiometry for single frequencies. Statistically significant differences were found for frequencies 0.25 Hz (p=0.017), 0.5 Hz (p=0.007), 1.0 Hz (p=0.018), and 3.0 Hz (p=0.034) and for air-bone gaps for 0.25 Hz (p=0.037) and 1.0 Hz (p=0.036) (Fig. 5, 6).

Comparison of hearing loss types between the groups revealed that among patients with perilymphatic fistulas conductive hearing loss and mixed hearing loss were most frequent (14 and 12 patients, respectively). Patients with labyrinthitis suffered primarily from mixed hearing loss (9 patients), similar to patients with facial nerve paralysis (5 patients). In patients

Tab. III. Differences in hearing thresholds at single frequencies and groups of frequencies on pure-tone audiometry between patients with different ECCSOM (single complications n=56 vs. multiple complications n=7).

Single frequency/ group of frequencies (kHz)	Air conduction (dBHL)			Bone conduction (dBHL)			Air-bone gap (dBHL)		
	S.C.	M.C.	P	S.C.	M.C.	P	S.C.	M.C.	P
0,125	58,0±25,7	76,4±31,2	0,134	-	-	-	-	-	-
0,25	57,6±26,0	75,7±34,0	0,252	34,6±31,8	54,3±45,7	0,185	23,0±13,0	21,4±16,8	0,337
0,5	58,9±25,7	73,6±32,1	0,475	36,6±31,0	49,3±37,2	0,349	22,3±11,6	24,3±12,4	0,982
0,75	59,8±25,6	75,7±28,3	0,244	35,8±31,0	50,7±36,9	0,171	24,0±11,5	25,0±13,0	0,868
1	61,4±26,6	77,1±28,8	0,297	37,2±32,0	52,9±36,3	0,155	24,2±12,3	24,3±12,4	0,868
1,5	64,0±26,9	77,1±29,7	0,481	41,9±30,9	55,7±36,3	0,275	22,1±12,3	21,4±10,7	0,596
2	61,3±27,1	75,7±30,1	0,391	45,4±31,0	55,7±35,5	0,429	15,8±10,7	20,0±11,2	0,825
3	67,9±29,2	77,9±33,0	0,758	52,6±32,2	65,7±40,7	0,496	15,4±10,1	12,1±8,6	0,171
4	73,5±28,5	83,6±31,3	0,809	59,7±31,2	71,4±36,8	0,448	13,8±8,3	12,1±9,5	0,122
6	79,0±28,6	86,4±26,7	0,929	67,9±32,3	75,7±31,8	0,604	11,2±8,7	10,7±8,9	0,084
8	75,7±32,5	89,3±29,5	0,790	-	-	-	-	-	-
0,5–1–2 (PTA)	60,5±25,9	75,5±30,1	0,357	39,9±30,8	52,6±36,3	0,263	20,8±10,6	22,9±11,3	0,991
4–6–8 (HTA)	76,1±28,8	86,4±28,3	0,742	-	-	-	-	-	-
0,5–1–2–4 (PMTA)	63,8±25,5	77,5±29,5	0,784	-	-	-	-	-	-
0,5–1–2–4–6–8 (OAA)	68,3±25,6	81,0±28,3	0,532	-	-	-	-	-	-

S.C.-single complications,

M.C.-multiple complications

with mastoiditis, mixed hearing loss was more frequent than conductive hearing loss (2 vs. 1 patient). Differences between the groups were statistically significant (p=0.012).

DISCUSSION

Data concerning the occurrence, severity, and type of hearing loss in ECCSOM are not homogeneous. In most studies, authors have analyzed hearing loss in larger groups of patients, including those suffering from extra- and intracranial complications. One of the aims of our study was to identify patients with single complications to compare the real effect of disease processes on hearing. In our study, patients suffered from mild to total hearing loss. In the study by Wu *et al.*, in a group of 285 patients with intra- and extracranial complications of CSOM, hearing loss was found in only 85 subjects (29.8%) [14]. The most prevalent extracranial complication in that study was labyrinthitis, which was found in 90 subjects of whom 78 had perilymphatic fistulas. In the study by Mostafa *et al.* [15], the most common extracranial complication was mastoiditis. Similar to our study, they found a comparable prevalence of labyrinthitis and perilymphatic fistulas (16.5% vs. 12.5%). Information concerning hearing loss in that report is scarce ("8 patients suffered from sensorineural hearing loss"), and the authors did not state due to what complications hearing loss was found in a group of 422 patients. It is worth noticing that the mean age of patients in that study was 50% lower than in our study (21.5 years vs. 50.3 years), and that the authors analyzed complications of acute and chronic otitis, which could explain the differences.

Data on hearing loss presented by Wu *et al.* are similar to the data obtained in our study; however, Wu *et al.* [14] did not state whether hearing loss in their study was only reported by patients or confirmed by additional tests. In our study, hearing loss was found in all patients. More information about hearing loss in patients with complications of CSOM has been presented by Leskinen and Jero [2]. In a group of 50 patients with extra- and intracranial complications, only 10 complications were caused by CSOM. Only 4 audiograms were obtained in that group, and 44 audiograms (88%) in the entire study sample. The authors concluded that the complications of CSOM seemed to cause permanent hearing loss from 30 dB to total deafness (mean PTA 60 dB) in 13 patients. Those authors diagnosed perceptive hearing loss (12%), mixed hearing loss (8%), and conductive hearing loss (6%). They also pointed out that

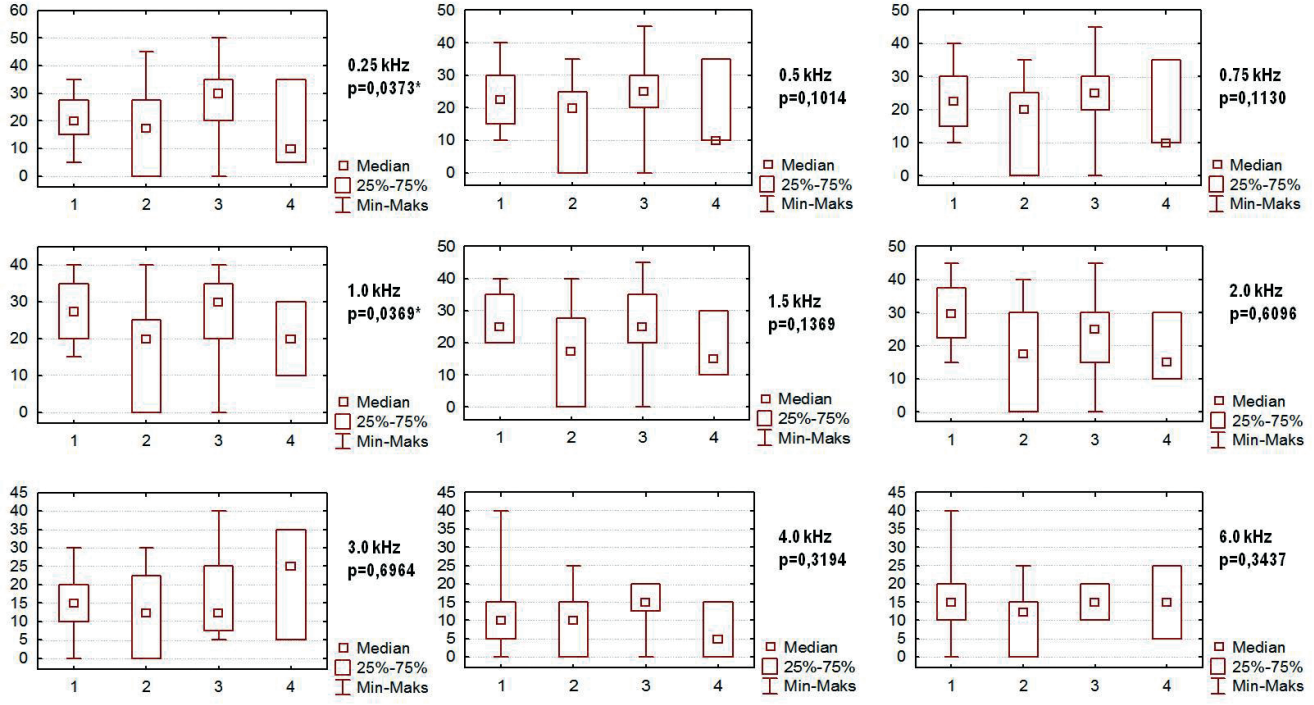

Fig. 6. Statistical significance of differences in hearing air-bone gaps on tonal audiometry for single frequencies for patients with different ECCSOM - 1. perilymphatic fistula (n=29) vs. 2. labyrinthitis (n=16) vs. 3. facial palsy (n=8) vs. 4. acute mastoiditis (n=3).

6 subjects with clear sensorineural hearing loss had labyrinthitis in the course of acute otitis media. In 5 patients (10%) with sensorineural hearing loss, the affected ear became deaf during follow-up. In our study, mixed hearing loss with at least a partial decrease of the bone curve on tonal audiometry, below 20 dB HL, was the most frequent finding that was present in over 50% of all patients. The second most frequent type of hearing loss in the study by Leskinen and Jero was complete deafness, which in our study constituted almost the same percentage of all affected ears [2]. We did not observe perceptive hearing loss as a single complication so frequently, and in our study it was least frequent (6.3%). The differences are perhaps due to different criteria used for the diagnosis of mixed and conductive hearing loss and the prevalence of acute otitis media complications in which the inner ear is not damaged as much as in chronic inflammation that we focused on. Moreover, the authors pointed out that labyrinthitis caused the most severe damage of the inner ear and thus is the single most disabling form of extracranial complication of CSOM. Similar observations were made based on audiometric analysis of our subjects. Yorgancılar *et al.* [16] described a group of 121 patients with intra- and extracranial complications of CSOM, and reported additional sensorineural hearing loss in 12 subjects, but those patients were not characterized in detail.

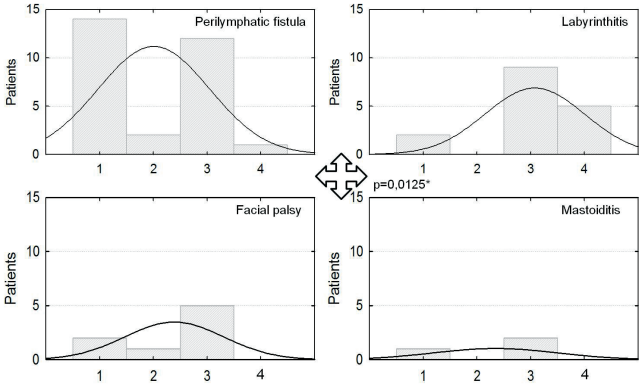

Fig. 7. Histograms of hearing loss types (1 – conductive hearing loss, 2 – sensorineural hearing loss, 3 – mixed hearing loss, 4 – total deafness) on tonal audiometry for patients with four types of ECCSOM.

Yang *et al.* [9] investigated a group of 78 patients with perilymphatic fistulas. They discovered that 47% of patients with destruction of the osseous labyrinthine wall with intact internal layer had conductive hearing loss, and 53% had sensorineural hearing loss of whom 9% were completely deaf. Twenty-eight percent of patients with invasion of the osseous labyrinthine internal layer, that caused direct contact of cho-

lesteatoma matrix with perilymphatic space or membranous labyrinth, had conductive hearing loss, and 72% had sensorineural hearing loss of whom 28% had complete deafness. Thirteen percent of patients with both osseous and membranous labyrinthine wall destroyed by cholesteatoma matrix had conductive hearing loss, and as many as 87% suffered from sensorineural hearing loss, with 33% with complete deafness. The authors concluded that greater extent of labyrinth destruction caused more severe hearing loss, mainly sensorineural. Moreover, hearing thresholds for air conduction were similar to those found in our study. In a study by Magliulo *et al.* [17], out of 92 subjects with labyrinthine fistulas, there were 5 cases of complete deafness of the affected ear. This concerned fistulas of the upper lateral semicircular canal, the vestibule in 1 case, and the cochlea in 2 cases. In our study, complete deafness was less frequent (1 in 29 patients). No hearing thresholds were provided for patients with fistulas. It was only stated that 25 patients were diagnosed with preoperative bone conduction characterized by BC-PTA < 30 dB. In a study by Gersdorff *et al.* [7], out of 54 subjects with labyrinthine fistula 28% had preoperative total deafness, 72% patients with extensive fistulas had conductive hearing loss, and 100% of patients with bone fistulas had conductive hearing loss. Similar to our study, there were no cases of mixed hearing loss, and 4 patients were diagnosed with facial nerve palsy and therefore they were classified as subjects with multiple complications. Manolidis [18] found 3 cases (13%) of total deafness among 23 patients treated for perilymphatic fistulas in the course of CSOM, and reported that deafness due to preoperative fistulas was found in 15% of patients. In our study, this value was lower (1/29, 3%).

In a study on facial nerve palsy in patients with CSOM, Yetiser *et al.* [10], similar to our study, observed that mixed hearing loss of the affected ears was the most frequent complication (21/23 cases of mixed hearing loss, 6/23 cases of total deafness, and 5/23 cases of conductive hearing loss). However, the group was not homogeneous as in our material, since 3 patients had multiple extra- and intracranial complications. Patients with conductive hearing loss had mean hearing thresholds ranging between 30 and 55 dB, while those with mixed hearing loss had mean hearing range between 47 and 95 dB. In our study, PTA AC was 57.1±14.3 dB, the second most severe hearing loss in our study. However, the general rule was confirmed that mixed hearing los of moderate severity is characteristic for ECCSOM Other authors have also reported coincidence of facial nerve palsy with other symptoms of inner ear damage, such as vertigo (15%) and tinnitus (5%) [19].

As regards hearing loss in acute mastoiditis due to CSOM, conductive hearing loss, mainly due to bone erosion, secondary infections, and mass effect caused by cholesteatomas is mild to moderate [3, 4, 20]. Most reports of acute mastoiditis describe this complication in children with acute otitis media, which is typically associated with conductive hearing loss. Few studies have reported a decrease in the curve of bone conduction and occurrence of mixed hearing loss as in our study [21].

In patients with CSOM, the prevalence of sensorineural hearing loss exceeding 10 dB for one of the tested frequencies oscillates between 45% and 76% [22]. Hearing loss occurs at all frequencies, especially high frequencies [3]. This observation is consistent with our study in which the highest hearing thresholds were obtained for 6 and 8 kHz frequencies. Yoshida *et al.* [23] investigated the effect of age on the hearing threshold of the bone curve on tonal audiometry in patients with CSOM. The analysis included the following frequencies: 250, 500, 1000, 2000 and 4000Hz. Similar to our study, this test was also conducted in a sound-reduced booth. The bone conduction thresholds were higher especially for high frequencies and in older age, and even after controlling for age the bone conduction impairment was higher by approximately 26% compared to healthy controls. This was thought to be caused by duration of CSOM and poor pneumatization of the mastoid air cells. The phenomenon was confirmed by other authors [24-26]. Similar studies were also carried out by Kolo *et al.* [25], who investigated hearing thresholds at the same frequencies as Yoshida *et al*., with regard to bone conduction in patients with CSOM. The thresholds that they obtained for bone conduction were higher than those obtained by us only by 3-5 dB, while the values of air-bone gaps were lower by approx. 20 dB in our patients, which indicates a more significant reception component of hearing loss, mainly in patients with mixed hearing loss due to ECCSOM.

More information on the pathological processes taking place in the inner ear in CSOM can be obtained in histological examinations. The cochlear basal turn is damaged most frequently, in which auditory cells responsible for the reception of high-frequency sounds are located. Pathological analyses revealed the presence of inflammatory cells in the scala tympani, especially in the basal turn and cochlear aqueduct, significant loss of hair cells and damage of stria vascularis in the basal turn of the cochlea [27]. This is in line with our study in which the highest hearing thresholds were obtained at 6 and 8 kHz and for the frequency group HTA (79.0±28.6, 79.0±28.6 and 76.1±29.0 dBHL, respectively). Paparella *et al.* [28] tried to explain the presence of sensorineural hearing loss in CSOM by referring to the passage of toxic substances through the round window membrane to the basal turn of the cochlea. The perceptive component of hearing loss in

ECCSOM undoubtedly results from the damage of the sensory epithelium in the inner ear. Most probably, this process begins long before the complication occurs and only exacerbates the existing pathological processes.

CONCLUSIONS

Hearing loss in ECCSOM is still a significant clinical problem. The dominant type of hearing loss is high-tone mixed hearing loss of moderate severity. Compared to previous data, our results are not identical, especially with respect to the type of hearing loss. ECCSOM causes permanent hearing loss from 30 dB to total deafness, with PTA of approximately 60 dBHL [2, 9, 10, 16]. Most commonly, sensorineural hearing loss is a cochlear complication of CSOM, although our work indicates that mixed hearing loss is most frequent in this infection of the middle ear, whereas sensorineural hearing loss is least common. In about 5-28% of patients with sensorineural hearing loss due to ECCSOM, the affected ear becomes deaf [2, 7, 9, 10, 15, 17, 18]. In our study, 11% of patients were diagnosed with complete deafness. Importantly, in this study we introduced a grading of hearing loss severity in patients with ECCSOM. The most severe hearing loss occurred in labyrinthitis, followed by facial nerve palsy and perilymphatic fistulas. It was least severe in acute mastoiditis, although the differences between complications were significant primarily for low frequencies for both air and bone conduction. There was no significant difference in the level of hearing loss between patients with single and multiple ECCSOM. Special care should be given to patients with labyrinthitis because of the risk of total deafness or severe mixed hearing loss due to CSOM and its cochlear complications.

BULLET POINT SUMMARY

- High-tone mixed hearing loss of moderate severity is characteristic for ECCSOM.
- 11% of patients develop total deafness, especially those with labyrinthitis.
- The most severe hearing loss occurs in labyrinthitis, followed by facial nerve palsy and perilymphatic fistulas. It is least severe in acute mastoiditis.

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ETHICAL STANDARDS

The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional guidelines on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008.

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