The Journal of International Advanced Otology

J Int Adv Otol 2020; 16(2): 241-7 • DOI: 10.5152/iao.2020.8150

Original Article

Pre- and Post-operative Speech Audiometry Evaluation in Patients with Chronic Otitis Media

Aleksandra Boron, Jacek Skladzien, Maciek Wiatr

Department of Otolaryngology, Jagiellonian University Medical College in Kraków, Poland

ORCID iDs of the authors: A.B. 0000-0002-7830-1327; J.S. 0000-0003-4778-1281; M.W. 0000-0003-0840-9268.

Cite this article as: Boron A, Skladzien J, Wiatr M. Pre- and Post-operative Speech Audiometry Evaluation in Patients with Chronic Otitis Media. J Int Adv Otol 2020; 16(2): 241-7.

OBJECTIVES: The primary function of the human auditory system is to ensure proper speech comprehension. Speech audiometry enables the assessment of the conductive and the sensory aspects of the ears, providing some insight into the central auditory processing function.

MATERIALS and METHODS: We conducted an analysis of 79 patients with chronic otitis media (COM) undergoing surgery at the Department of Otolaryngology, Jagiellonian University Medical College, in Kraków between 2005 and 2014. Tonal audiometry and speech audiometry were used as part of the hearing assessment. The pre-operative and long-term post-operative findings were compared, focusing mainly on speech audiometry.

RESULTS: At the end of the mean 10-year follow-up, a significant percentage worsening in speech comprehension from the baseline was demonstrated in group III (hearing loss > 70 dB(decibels)), as compared with the remaining groups. There was a significant (p=0.017) difference in speech comprehension between the treated and contralateral ears, with the mean maximum speech comprehension rates of 80% in the treated ear versus 92% in the contralateral ear.

CONCLUSION: We demonstrated a correlation between the findings of tonal audiometry and speech audiometry. The severe damage caused by chronic middle ear diseases not only leads to conductive hearing loss but also acts as a significant contributor to poor speech comprehension in a long-term follow-up. The speech comprehension in a healthy ear is significantly better than in a diseased ear. Middle ear reconstructive surgery offers the maximum improvement in speech comprehension at the hearing loss of 41 to 70 dB in speech audiometry.

KEYWORDS: Speech audiometry, chronic otitis media, tympanoplasty

INTRODUCTION

The human auditory sense is intended to ensure accurate speech perception and comprehension. Subjective tests, such as tonal and speech audiometry, play an important role in the diagnosis of hearing abnormalities. Used for screening, tonal audiometry makes it possible to estimate the degree of hearing loss and to indicate its type. Speech audiometry, in contrast, can help evaluate hearing by characterizing its communication performance. Speech audiometry enables the assessment of conductive and sensory aspects of the hearing organ, providing some insight into the central auditory processing function. Speech comprehension is a valuable parameter in the assessment of hearing pathology. Although the frequency of human speech ranges from 20 Hz (Hertz) to 20 kHz (Kilohertz) [1,2], some authors indicate these frequencies to be between 14 Hz and 14 kHz for national languages. If it corresponds to the "range of speech intelligibility," it is between 1 Hz and 4 kHz [2,3]. A speech audiogram is plotted onto the reference curve obtained from people with normal hearing, with the percentage of correctly comprehended presented speech stimuli as the ordinate and sound volume as the abscissa. Speech audiometry text may contain monosyllabic words, multisyllabic (bisyllabic, trisyllabic, or more) words, numbers or even sentences [3]. They are always typical of the language spoken by a given population. The first speech audiometry text was developed by H. Fletcher in 1929 [3]. The first Polish speech audiometry text was developed in 1953 by Zakrzewski, Suwalski, Antkowski, and Suwalski [4].

Pre- and post-operative assessment of patients with middle ear pathologies mainly relies on tonal audiometry. When assessing patients with chronic otitis media (COM), we hardly ever focus on speech comprehension, with clinical decision-making usually based

Corresponding Address: Maciej Wiatr E-mail: maciej.wiatr@uj.edu.pl

Submitted: 01.30.2020 • **Accepted:** 05.04.2020 • **Available Online Date**: 05.11.2020
Available online at www.advancedotology.org

on tonal audiometry. However, speech audiometry reflects the social aspects of auditory performance.

Chronic otitis media is a common ear disease that manifests as conductive hearing loss. In the active form of this disease, there will also be periodic or permanent otorrhea and tympanic perforation.

With a number of surgical techniques available depending on intraoperative findings, otosurgery is the treatment of choice in such cases. The goals for surgery for COM are eradication of the disease (safe ear), grafting of the perforation, if it exists (dry ear), and reconstruction of the ossicular chain (hearing ear), together with well-aerated ear [5].

The aim of the study was to analyze long-term functional outcomes (i.e., improvement in speech audiometry) of surgical treatment in patients with COM.

MATERIALS AND METHODS

We carried out an analysis of 79 patients with COM undergoing surgery between 2005 and 2014. Patients with incomplete medical records, who did not report for control, and those operated for otosclerosis or middle ear tumor were excluded. Patients who did not consent to a hearing test and did not completed the questionnaire were excluded. The youngest patient was 27 years old, and the oldest one was 78 years old, with the mean age of 57.1 years. Fifty-one women and 28 men were enrolled. Forty of them (50.6%) had their right ear operated on, and 38 of them (49.4%) had the left ear operated on. Fifty-seven (72.2%) patients underwent their first surgery and did not require any further procedure, whereas 22 (27.8%) patients were re-operated. In 27 (34.2%) patients, the endaural approach was chosen, whereas in 52 (65.8%) patients, the postauricular approach was used.

On the basis of the questionnaire completed during the remote control, only 2 patients (2.5%) reported post-operative taste disturbances. No facial nerve palsy was noted, but perioperative deafness was found in 2 patients (2.5%). Tinnitus before the surgery was reported by 33 patients (41.7%). In most cases it decreased; only 4 patients (5%) reported increase in tinnitus. Twenty-three patients (29%) experienced dizziness.

Thirty-eight patients (48%) reported subjective hearing improvement after otosurgery, and the remaining 41 patients (52%) did not notice hearing improvement or even reported deterioration. Twenty-five patients (31.6%) required hearing aid, of which, 17 (21.5%) required air conduction hearing aids, and bone-anchored hearing aid (BAHA) was inserted in the ears of 8 patients (10.1%). One patient suffered from sudden deafness of the operated ear 3 years after the surgery. The implemented treatment did not bring any improvement.

Most patients (74.6%) reported recurrent otitis media from childhood. Only 5 patients (6.3%) had adenoidectomy in daycare; no patient had a cleft palate. In 4 patients (5%), the indication for surgery was otogenic meningitis.

Pre-operative tympanic membrane perforation occurred in 77 patients (97.5%), of which the tympanic membrane defect of over 50% occurred in half of the patients. In remote control, perforations were diagnosed in 17 patients (21.5%), 10-80% in size. In contrast, 25 patients (31.6%) had retraction pockets in long control. Otorrhea from the operated ear appeared in 13 patients (16.5%), 3 years after the surgery, on the average.

Pure tone audiometry and speech audiometry were used as a part of hearing assessment. The tests were performed with an audiometer equipped with TDK 39® (MIDIMATE 622, Madsen, Dybendalsvænget, Taastrup, Denmark). The pre-operative and long-term post-operative findings were compared. The follow-up duration was from 5 to 14 years.

In order to analyze speech audiograms, we divided the patients into the following groups on the basis of the maximum hearing loss (expressed in dB of the words given in speech audiometry) for which the best speech comprehension was achieved.

Group I: 0-40 dB
Group II: 41-70 dB
Group III: 71-100 dB

In order to ensure reliable analyses, the patient groups were comparable in terms of patient number and their mean age.

All the patients consented to the surgery and participation in the study, and the approval of the Local Bioethical Committee was obtained to conduct the study (no. 122.6120.206.2016).

Statistical Analysis

Statistical analysis was performed with a significance level of 5%. Statistica software (ANOVA; Statistica, StatSoft, Krakow, Poland) was used for statistical analysis.

RESULTS

The outcomes of 79 patients were analyzed. Canal wall-up (CWU) tympanoplasty was performed in 52 patients and canal wall-down (CWD) tympanoplasty in the remaining 27 patients. The procedure was limited to tympanotomy in 38 patients and in the remaining 41 patients to atticotomy or atticoantromastoidectomy (Figure 1).

No abnormalities of middle ear lining were demonstrated in 52 patients. In the remaining 27 cases, inflammatory granulation and/or cholesteatoma removal was required.

For the tympanic membrane reconstruction, temporalis fascia graft and/or cartilage perichondrium were used (Figure 2).

MAIN POINTS

- Severe damage in COM contributes to poor speech comprehension.
- Speech comprehension is always better in healthy ear.
- Reconstruction of middle ear gives the best improvement in speech comprehension at the hearing loss of 41-70 dB in speech audiometry.

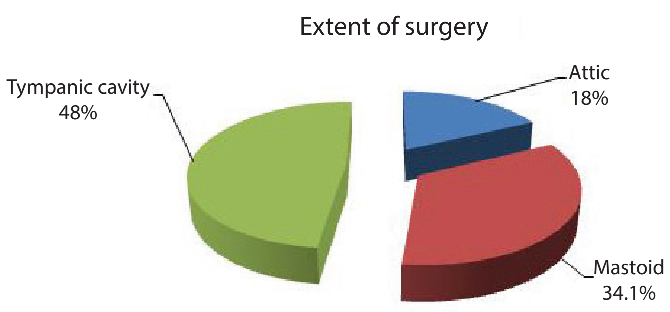

Figure 1. The extent of surgery in the study sample.

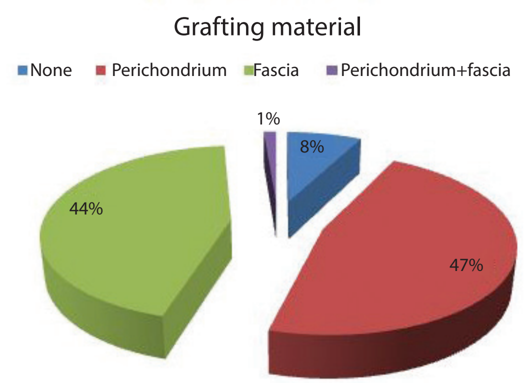

Figure 2. Type of grafting material used for tympanic membrane reconstruction.

In an attempt to evaluate treatment outcomes in terms of changes

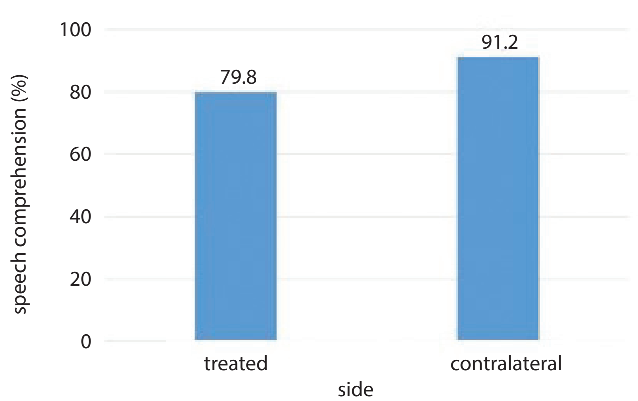

Figure 3. The mean maximum difference in speech comprehension between the treated ear and the contralateral ear.

in the social hearing performance, further analysis was based on speech audiograms. No studies are available to address this aspect of hearing assessment in patients with COM.

Pure tone audiometry and speech audiometry were performed preoperatively and postoperatively in each enrolled patient. The pre-operative audiograms were compared with those obtained at the end of 5-14 days of follow-up.

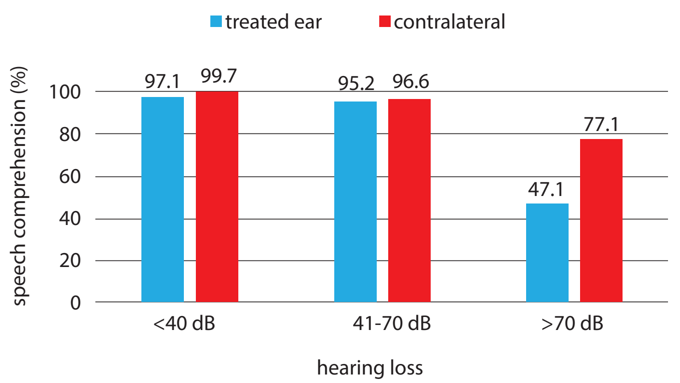

Figure 4. Speech comprehension in treated and untreated ears for different hearing loss levels.

Table 1. Speech comprehension levels in different hearing loss level groups assessed preoperatively and postoperatively

Hearing loss	Before surgery Speech comprehension level (%)	After surgery Speech comprehension level (%)	p
I (up to 40 dB)	91.8	97.1	p=0.86
II (41-70 dB)	72.9	95.2	p=0.011
III (above 70 dB)	71.4	47.1	p=0.135

The findings were analyzed in the context of tympanoplasty, comparing the treated and the contralateral (healthy) ears, and analyzing the differences between pre- and post-operative speech audiograms. Speech audiometry values in the second, untreated ear compared with changes in speech comprehension in the operated ear enabled to eliminate inter-individual variability with time. The assumption behind this is the second ear could be the point of reference for the changes in speech comprehension tests performed long after ear surgery.

There was a significant (p=0.017) difference in speech comprehension between the treated and contralateral ears, with the mean maximum speech comprehension rate of 79.8% in the treated ear versus 91.2% in the contralateral (untreated) ear (Figure 3).

There was no significant hearing impairment in the contralateral (untreated) ear over the mean 10-year follow-up.

The two-way analysis of variance (ANOVA), with assessed ear (treated vs. untreated) and hearing loss (three ranges) as independent variables, demonstrated no significant difference in speech comprehension over time in groups I and II. However, in group III, there was a significant change in speech comprehension during the follow-up period (Figure 4).

Further analysis focused on comparing pre- and late post-operative speech audiograms. The performed surgery best improved speech comprehension in group II (hearing loss 41-70 dB). In group III (above 70 dB), speech comprehension deteriorated, whereas in group I (hearing loss up to 40 dB), the percentage of speech com-

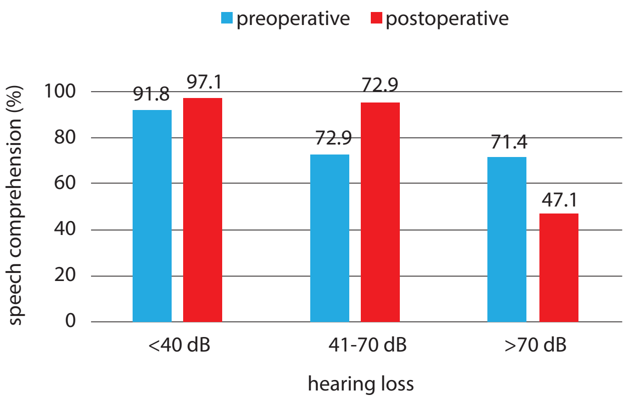

Figure 5. Speech comprehension levels in different hearing loss level groups assessed preoperatively (blue) and postoperatively (red).

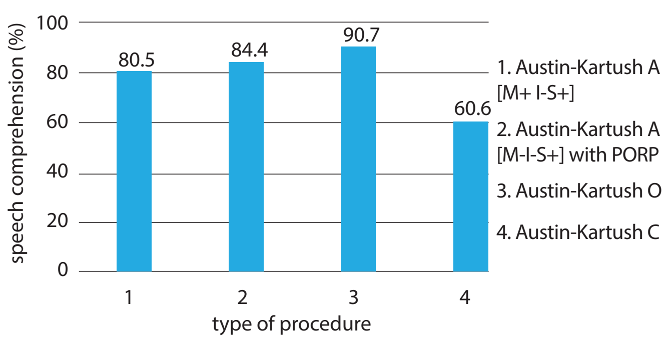

Figure 6. Speech comprehension levels in groups based on the extent of auditory ossicle reconstruction.

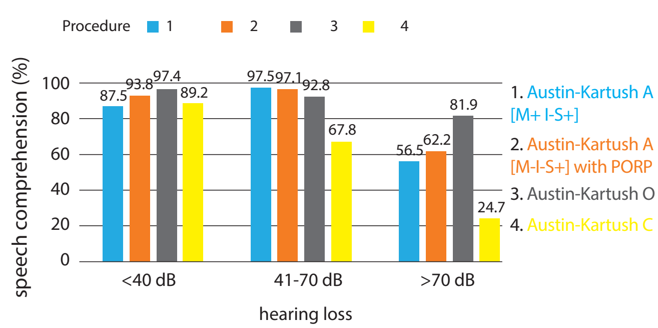

Figure 7. Speech comprehension levels in groups based on the extent of ossicle reconstruction depending on hearing loss, for which the best speech audiogram was obtained.

prehension remained at a similar to the pre-operative level (Figure 5, Table 1).

Speech audiograms were also analyzed against the type of surgery performed. We assumed a division based on the extent of tympanoplasty performed. We used Austin-Kartush classification/Wullstein classification.

Procedure # 1 (n = 19): Austin-Kartush A (M+ I-S+)/tympanoplasty type II
Procedure # 2 (n = 13): Austin-Kartush A (M-I-S+)/tympanoplasty type II (with use PORP)
Procedure # 3 (n = 20): Austin-Kartush O/tympanoplasty type I
Procedure # 4 (n = 27): Austin-Kartush C/tympanoplasty type III

Statistical analysis with ANOVA demonstrated a significant difference ($p<0.0001$) between the surgery type-based groups. Patients after procedure # 4 had significantly worse speech comprehension than those after other procedures (Figure 6).

Further analysis with two-way ANOVA included hearing loss (groups 1-3) and the extent of surgery (procedures #1-#4) as independent variables (Figure 7).

A comparison of post-operative speech audiograms demonstrated no significant differences between procedures #1, #2, #3, and #4 in patients who presented the best speech comprehension at the hearing loss below 70 dB ($p=0.055$). However, it also demonstrated that significant damage to the ossicular chain induced by procedure #4 was associated with worse speech comprehension than other procedures if the hearing loss for the best attained speech audiogram was above 70 dB (group III, $p=0.002$).

In the next step, correlations were determined between tonal and speech audiograms in the hearing loss-based groups. The correlation between the two audiograms was weak in group I (hearing loss up to 40 dB), moderate in group II (hearing loss 41-70 dB), and very strong in group III (hearing loss above 70 dB) (Figures 8 and 9). In each case, the correlation coefficient was negative, which indicated an inverse association.

The correlation between air conduction and speech audiometry and the correlation between bone conduction and speech audiometry were comparable. The results are presented in Table 2.

DISCUSSION

The beneficial effect of middle ear reconstruction on the inner ear (including the contralateral, untreated inner ear) was discovered and documented by Professor Jan Miodoński in 1956 in his paper entitled "Fenestracja poza otosklerozą. Fenestracje nietypowe, drenaż cysterny" (Fenestration in diseases other than otosclerosis, atypical fenestration, and drainage of the cisterna) [6]. The effect of middle ear mechanics on the inner ear function has been studied for many years. There are reports of a significant improvement in bone conduction in some patients after ossiculoplasty and stapedotomy, which is a measure of the effect of middle ear mechanics on the organ of Corti [7-9].

Simple and inexpensive diagnostic tools, such as tonal or speech audiometry, may facilitate analysis of different aspects of surgery (surgical approach to the temporal bone, selection of reconstructive material, etc.), indicating treatment efficacy in reconstructing the sound conductive system in the middle ear and restoring the effect of middle ear mechanics on the function of the inner ear.

In group I, identified on the basis of hearing loss for which the best results were achieved in speech audiometry, the maximum speech comprehension was 99.7% in the healthy ear and 97.1% in the treated ear. In group II, the between-ear difference was also small (96.6% in the healthy ear versus 95.2% in the treated ear). Only in group III, where best responses were achieved for the hearing loss above 70

Table 2. Correlation between audiometry findings and speech comprehension at three volume levels

		Hearing loss					
Conduction	Frequency	up to 40 dB (n=88)		41–70 dB (n=105)		above 70 dB (n=115)	
Bone	500 Hz	r = −0.2625	Weak	r= -0.4382	Moderate	r= −0.6103	Strong
	1000 Hz	r = −0.3352	Weak	r= −0.3585	Weak	r= −0.6552	Strong
	2000 Hz	r = −0.1482	Very weak	r= −0.3158	Weak	r= −0.6954	Strong
	Moderate	r = −0.2829	Weak	r= −0.4221	Moderate	r= −0.6896	Strong
Air	500 Hz	r = −0.3173	Weak	r= −0.3563	Weak	r= −0.6259	Strong
	1000 Hz	r = −0.2815	Weak	r= −0.3482	Weak	r= −0.6827	Strong
	2000 Hz	r = −0.1144	Very weak	r= −0.3197	Weak	r= −0.7081	Strong
	Moderate	r = −0.1537	Very weak	r= −0.4049	Moderate	r= −0.7312	Strong

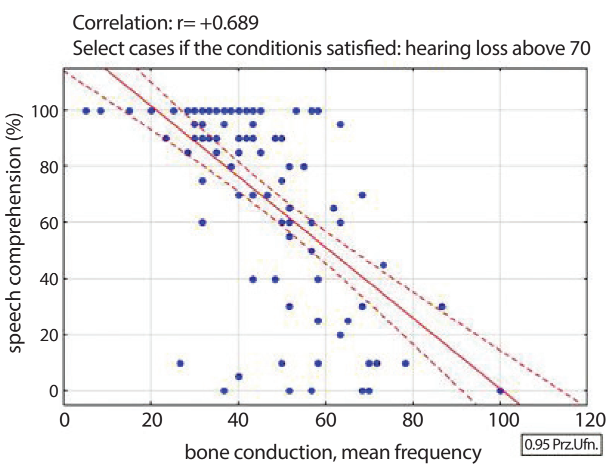

Figure 8. Correlation between the mean bone conduction and speech audiometry in group III with the best attained audiogram at the hearing loss over 70 dB.

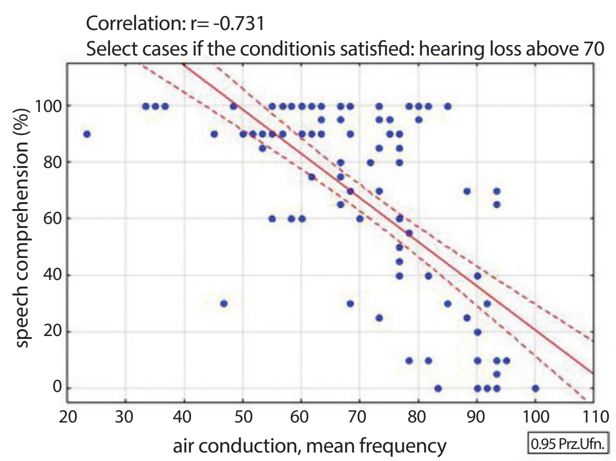

Figure 9. Correlation between the mean air conduction and speech audiometry in group III with the best attained audiogram at the hearing loss over 70 dB.

dB, the difference was significant—77.1% vs. 47.1% in the healthy and treated ears, respectively, p=0.02.

This confirms that speech comprehension in the contralateral (i.e., untreated, healthy) ear is significantly superior to that in the treated ear. Therefore, the improvement in speech audiometry was only significant for the hearing loss above 70 dB. This finding confirms that the treated ear is more prone to inner ear damage. This may result from the spread of inflammation from the middle ear to the inner ear, the effect of exposure to noise during drilling into the temporal bone, and the fact that abnormal acoustic wave transmission may affect the damage to the organ of Corti [10-12]. In contrast, in distant control, worse speech understanding in group III (hearing loss > 70 dB) occurs on both sides, which suggests that not only the type of otosurgery affects hearing results but also observation time, possible exposure to noise, inflammation, or excessive unheated ear load.

The performed surgery best improved the speech comprehension in group II (hearing loss 41-70 dB), where the best attained percentage of speech comprehension increased from 72.9% (pre-operative) to 95.2% at the end of the follow-up (p=0.011). The situation was quite different in patients who attained the best pre-operative speech audiometry results for the hearing loss above 70 dB. At the end of the follow-up, the speech comprehension in this group dropped from 71.4% preoperatively to 47.1%. The difference, albeit large, was not significant (p=0.13), attributable to the high variability of speech comprehension obtained in this group. In group I (best speech audiometry results for the hearing loss up to 40 dB), the percentage of speech comprehension remained at a similar level or increased slightly (91.8% preoperatively vs. 97.1% at the end of the follow-up). The above finding indicates that the pre-operative speech audiometry result is a prognostic factor for the post-operative social auditory performance. This perspective on hearing improvement after middle ear surgery in patients with COM is an original observation.

If the best speech audiometry results were achieved for the hearing loss above 70 dB (group III), speech comprehension was significantly worse after procedure #4 as compared with the remaining procedures (p=0.002). The largest difference in post-operative speech comprehension levels was between procedure #3 (tympanoplasty type I) and procedure #4 (tympanoplasty type III), which caused the greatest damage to the sound conductive system. Patients who underwent tympanoplasty type III had a long-term (since childhood) history of COM (91%), which favored the possible toxic, inflammatory metabolic products of the middle ear to act on the internal ear.

No patient had a history of cleft palate, which is an important risk factor for COM. In 4 patients (5%), the indication for surgery was otogenic meningitis, which increased the inner ear damage. In addition, dizziness partly resulted from a semicircular canal fistula, which decreased after surgery and also had an influence on the inner ear function. Moreover, reoperations are a negative prognostic factor for hearing improvement.

Another factor that worsens speech understanding is age-related hearing damage. In the study group, the average age of patients was 57.1 years, and the majority of respondents (79.7%) were older than 50 years.

The effect of otosurgery on the inner ear function has been debated for a number of years. Vartiainen et al. [13] did not observe any post-operative changes in bone conduction in 92% of their patients undergoing middle ear surgery owing to COM. In the remaining 5% of patients, the improvement in bone conduction was significant, reflecting the functional improvement in the inner ear. Only the intact middle ear sound conductive system favorably affects bone conduction. In practice, it comes down to improved bone conduction in patients treated for otosclerosis (marked by the presence of the Carhart notch) and COM, yet only those with a preserved or only slightly impaired ossicular chain.

Many researchers reported a link between the middle ear pathology and inner ear function [14,15]. Severe COM with cholesteatoma, mucosal abnormalities in the inner ear, and an impaired ossicular chain negatively affect the inner ear. They all impact the ossicular chain mechanism, which is reflected in speech audiograms [15, 16]. As demonstrated in our study, the worst post-operative speech audiometry results were shown in patients with a long history of COM, after procedure # 4 and after reoperation, which are negative prognostic factors for hearing improvement. In some studies, the only factor that affects hearing loss is reoperation and damage to the stapes. The reason for reoperation is residual or recurrent disease and no hearing improvement [17, 18]. To date, there have been no studies to analyze speech audiograms in patients with COM. The available speech audiometry research focuses mainly on different types of tests such as speech audiometry in silence and speech-in-noise tests or assessing the beneficial effect of a cochlear implant or hearing aid on speech comprehension [19,20].

Our analysis sheds new light on post-operative social hearing performance in patients with COM.

CONCLUSION

Whereas speech audiogram correlates with bone and air conduction for all hearing loss levels, it is not linked to the air-bone gap (ABG). The speech comprehension in the healthy ear is significantly better than in the diseased ear. A significant decrease in speech comprehension at above 70 dB is noted after middle ear surgery, which results from the inflammatory damage to the inner ear, reflected by the presence of loudness recruitment. Middle ear reconstructive surgery offers the maximum improvement in speech comprehension at the hearing loss of 41-70 dB in speech audiometry. There is a correlation between severe sensorineural hearing loss and worse speech audiometry results. The severe damage caused by chronic middle ear diseases not only leads to conductive hearing loss but also acts as a significant contributor to poor speech comprehension in the long-term follow-up.

Ethics Committee Approval: Ethics committee approval was received for this study from the Ethics Committee of Jagiellonian University (18.05.2017-Nr 1072.6120.2.2017).

Informed Consent: Written informed consent was obtained from each participant of the study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - A.B. ,M.W.; Design - A.B. ,M.W.; Supervision - J.S. ; Resource - A.B.,M.W., J.S. ; Materials - A.B. ; Data Collection and/or Processing - A.B. ; Analysis and/or Interpretation - A.B. ,M.W. ,J.S. ; Literature Search - A.B. ,M.W. ; Writing - A.B. ,M.W. ,J.S. ; Critical Reviews - M.W., J.S.

Conflict of Interest: The authors have no conflict of interest to declare.

Financial Disclosure: The authors declared that this study has received no financial support.

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