

ORIGINAL ARTICLE

Prognostic Factors for Hearing Preservation in Surgery of Chronic Otitis Media

Viktor Chrobok, Arnost Pellant, Milan Meloun, Karel Pokorny, Eva Simáková, Petra Mandysová

Department of Otolaryngology and Head and Neck Surgery, Regional Hospital of Pardubice (VC, AP, KP)

Faculty of Health Studies, University of Pardubice (VC, AP, PM)

Faculty of Chemical Technology, University of Pardubice (MM)

Department of Pathology, University Hospital, Charles University, Hradec Králové (ES), Czech Republic, Europe

Objectives/Hypothesis: The aim of this study was to observe the impact of prognostic factors (the Middle Ear Risk Index [MERI] by Becvarovski and Kartush) on hearing of patients surgically treated for chronic otitis media. Furthermore, the aim of the study was to determine which of the monitored factors (otorrhea, eardrum perforation, cholesteatoma, ossicular status, middle ear granulations or effusions, previous surgery, and smoking) were linked to greater hearing impairment.

Study Design: Retrospective case review.

Materials and Methods: The level of hearing was assessed for each preoperative prognostic factor category in a total of 155 patients surgically treated for chronic otitis media at the Department of Otolaryngology and Head and Neck Surgery in Pardubice, Czech Republic, between 1996 and 2004. A pre-op and post-op statistical analysis of each patient's hearing was conducted by pure-tone audiometry using the MERI.

Results: Patients with a perforated eardrum had poorer hearing than patients with an intact eardrum at frequencies of 0.5 to 3 kHz before surgery and at all frequencies after surgery (by 7 to 13 dB, $p < 0.05$). Statistically, patients with cholesteatoma had a much greater air conduction hearing loss, i.e. by 8 to 18 dB ($p < 0.05$), at all frequencies both pre-op and post-op compared to patients without cholesteatoma. Patients with an intact ossicular chain had the best pre-op and post-op hearing; their hearing was significantly better compared to a group of patients suffering from a defective incus and compared to a group of patients with defects apparent in ($p < 0.05$). In patients undergoing revision surgery, pre-op and post-op air conduction was significantly worse compared to a group of patients with a history of a different type of ear operation prior to this study ($p < 0.05$). Smokers had a lower pre-op and post-op hearing threshold; however, a significant difference was found only at high-frequency air conduction (3 and 4 kHz) post-op, when it deteriorated by 14 and 12 dB ($p < 0.05$).

No major hearing threshold difference was found between patients who either had or did not have middle ear granulations and otorrhea.

Patients with a generally lower MERI had better pre-op and post-op air and bone conduction than patients with a higher MERI ($p < 0.05$). In patients with a MERI of 0 to 3 (minor disorder), post-op air conduction at frequencies of 0.5 to 3 kHz improved by 4 to 6 dB. In a group with a MERI of 4 to 6 (a moderate disorder), air conduction at frequencies of 3 and 4 kHz deteriorated by 4 and 5 dB, and in patients with a MERI of 7 or higher (a severe disorder), air conduction declined at all frequencies by 1 to 7 dB.

Conclusions: An evaluation of pre-op and post-op hearing revealed that highly significant pre-op negative prognostic factors included the presence of cholesteatoma, the presence of perforation of the tympanic membrane, ossicular status, previous surgery, and the overall sum of the MERI. Smoking was a less significant negative factor. Minor prognostic factors included the presence of middle ear granulations and otorrhea. Patients with a higher overall MERI had a more severe impairment of air and bone conduction hearing threshold pre-op and post-op compared to patients with a lower MERI.

Submitted : 28 January 2009

Accepted : 20 July 2009

The goals of a surgical treatment of chronic otitis media include removal of inflammation and creation of a sound-conducting mechanism in the well-aerated, mucosa-lined middle ear cleft. Numerous prognostic factors affecting hearing among patients with a chronic

otitis media have been discussed in the literature.^[1-4] Becvarovski and Kartush assessed risk factors for chronic suppurative otitis media using the Middle Ear Risk Index (MERI).^[5-7] The factors they monitored included otorrhea, perforation of the eardrum,

Corresponding address:

Viktor Chrobok

Department of Otolaryngology and Head and Neck Surgery, Regional Hospital, Kyjevska 44, 532 03 Pardubice, Czech Republic, Europe.

E-mail: viktor.chrobok@nemocnice-pardubice.cz

Acknowledgments

This study was supported by a grant project of the Czech Ministry of Health No. NR 8376-3/2005. The authors thank Dr. Zoran Becvarovski M.B.B.S., F.R.A.C.S for reading the manuscript.

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cholesteatoma, ossicular status, middle ear granulations or effusions, previous surgery and smoking, and they assigned a risk value to each of these factors.

The aim of our study was to evaluate prognostic risk factors for chronic otitis media, characterizing the patient's condition from the perspective of pre-op and post-op hearing. Moreover, the aim of the study was to determine clinical significance of individual factors based on a statistical evaluation. Becvarovski and Kartush evaluated the condition of the ear based on post-op otoscopic findings alone. However, our study presented a new viewpoint as it was based on a comparison of pre-op and post-op hearing thresholds using the MER index.

Materials and Methods

This retrospective study entailed an assessment of 266 patients suffering from chronic otitis media, who underwent a total of 310 operations on the temporal bone between July 1996 and December 2004 at the Department of Otolaryngology and Head and Neck Surgery at the Regional Hospital of Pardubice, Czech Republic.

The following items were assessed in the retrospective review of data obtained from healthcare documentation (case records, surgery reports, out-patient cards):

- otorrhea, perforation of eardrum, cholesteatoma, ossicular chain status, middle ear granulations or effusions, previous surgery and smoker, to which a risk value was assigned, specified in parentheses together with the type of prognostic factor (Table 1). The sum of risk values gave the MERI index. The MERI value determines the seriousness of prognostic factors, which allowed to divide patients into three groups: a total MERI of 0 to 3, 4 to 6 and 7 or more, representing a minor, a moderate, and a serious disorder, respectively.
- hearing examined by pure-tone audiometry prior to surgery - air and bone conduction at frequencies of 0.5, 1, 2, 3 and 4 kHz
- hearing examined by pure-tone audiometry at least one year after surgery - air and bone conduction at frequencies of 0.5, 1, 2, 3 and 4 kHz

Table 1. Middle ear risk index

otorrhea	dry - 0
	occasionally wet - 1
	persistently wet - 2
	wet, cleft palate - 3
perforation of eardrum	none - 0
	present - 1
cholesteatoma	none - 0
	present - 2
ossicular chain status	malleus, incus and stapes present - 0
	defect of incus - 1
	defect of incus and stapes - 2
	defect of incus and malleus - 3
	defect of malleus, incus and stapes - 4
	ossicular head fixation - 2
middle ear: granulations or effusions	stapes fixation - 3
	no - 0
previous surgery	yes - 2
	none - 0
	staged - 1
smoker	revision - 2
	no - 0
	yes - 2

Comprehensive data were obtained from 155 patients (90 men and 65 women), who were included in a further follow up. The average post-op follow-up period was 3.3 years (from 1 to 9.5 years). Temporal bone surgical procedures included two cases of cortical simple mastoidectomy (note: patients with acute mastoiditis were not included in the monitored group), 51 cases of atticotomy, 62 cases of modified radical mastoidectomy, 5 cases of radical mastoidectomy, 24 cases of revision after modified radical mastoidectomy, and 11 cases of resection of the retraction pocket with reconstruction using a tragal cartilage.

Modified radical mastoidectomy and radical mastoidectomy were combined with the canal wall down technique. We used lateral graft tympanoplasty. Patients with simple dry perforations were not included in the study. The following ossicular reconstruction methods were used: myringostapediopexis in 18 cases, incus interposition in 3 cases, partial ossicular replacement prostheses (PORPs) in 2 cases, and total ossicular replacement prostheses (TORPs) in 24 cases. All surgeries were one-stage or first-stage procedures; second-stage procedures were not included.

Statistical method

The two-sample Hotelling's test was used to examine the equality of the mean vectors of two populations. The test was carried out under the assumption that each population had a multivariate normal distribution, the two samples were independent, and the two covariance matrices were equal. The null hypothesis that the means of the two populations were equal was accepted if the calculated significance level p was lower than the set significance level $\alpha = 0.05$.

Results

1. Hearing thresholds of patients based on otorrhea

In the pre-op evaluation of hearing based on otorrhea, no significant difference was found between hearing thresholds (Figure 1). After surgery, 22 patients without secretion had better hearing than 84 patients with occasional drainage and than 44 patients with permanent secretion; a significant difference was found between the non-secretion group and the permanent-drainage group after surgery at air conduction frequency of 3 kHz ($p < 0.05$) and at bone conduction frequencies of 3 and 4 kHz ($p < 0.05$). In patients without drainage,

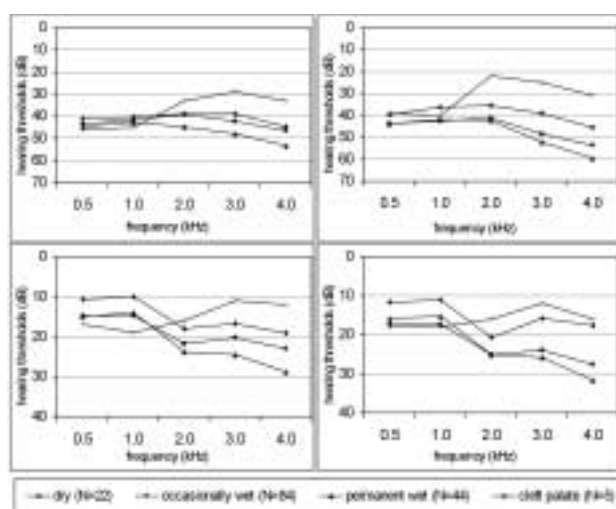


Figure 1. Air conduction before (top left) and after (top right) surgery based on the presence of otorrhea before surgery. A significant difference was found between the non-secretion group and the permanent-secretion group after surgery at a frequency of 3 kHz ($p = 0.05$). Bone conduction before (bottom left) and after (bottom right) surgery based on the presence of otorrhea before surgery. Significant differences were found between the non-secretion group and the permanent-secretion group after surgery at frequencies of 3 and 4 kHz ($p = 0.03, 0.02$).

post-op air conduction across frequencies 0.5/1/2 kHz improved by 2 to 4 dB and bone conduction at 3 and 4 kHz improved by 1 to 2 dB. Conversely, patients with an occasional or permanent drainage experienced deterioration in hearing at all air conduction frequencies by 1 to 7 dB and at bone conduction frequencies by 1 to 4 dB. Patients with permanent secretion recorded the lowest pre-op and post-op air and bone conduction hearing threshold.

A group of five patients with a cleft palate had an unusual form of average audiometric curve, with a decline in the deep frequencies in particular; post-op, air conduction improved at all frequencies by 2 to 11 dB and bone conduction improved only at 1 kHz (by 1 dB).

2. Hearing thresholds of patients based on the presence of eardrum perforation

In 86 patients with perforation of the eardrum, the average loss of air and bone conduction hearing before and after surgery was greater compared to a group of 69 patients with an intact eardrum (Figure 2). The differences in air conduction ranged from 6 to 8 dB before surgery, with a statistical significance at

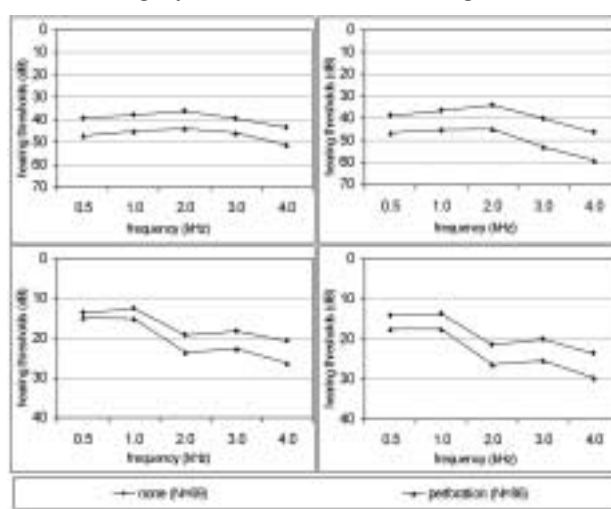


Figure 2. Air conduction before (top left) and after (top right) surgery based on the presence of perforation of the tympanic membrane. The differences before surgery were statistically significant at frequencies of 0.5 - 3 kHz ($p = 0.01, 0.02, 0.02, 0.01$) and after surgery, at all the monitored frequencies ($p = 0.02, 0.02, 0.004, 0.003, 0.007$). Bone conduction before (bottom left) and after (bottom right) surgery based on the presence of perforation of the tympanic membrane. There was no statistical difference.

frequencies of 0.5 - 3 kHz ($p < 0.05$) and from 8 to 13 dB after surgery, with a statistical significance at all the monitored frequencies ($p < 0.05$). After surgery, there was a reduction in air conduction (especially in the group of patients with eardrum perforation) at frequencies of 3 and 4 kHz (by 8 dB).

The differences between bone conduction in the individual groups before and after surgery were up to 3 dB, the differences between the groups were up to 6 dB (Figure 2).

3. Hearing thresholds of patients based on the presence of cholesteatoma

Average air and bone conduction in 98 patients with chronic otitis media with cholesteatoma was worse than in 57 patients with chronic otitis media without cholesteatoma (Figure 3). The differences were around 10 dB and were statistically significant at all the monitored pre-op and post-op air conduction frequencies ($p < 0.05$) as well as at a bone conduction frequency of 4 kHz post-op ($p < 0.05$). After surgery, the group of patients without cholesteatoma experienced an improvement in the hearing threshold at 0.5, 1, and 2 kHz (by 1 to 2 dB), while there was a

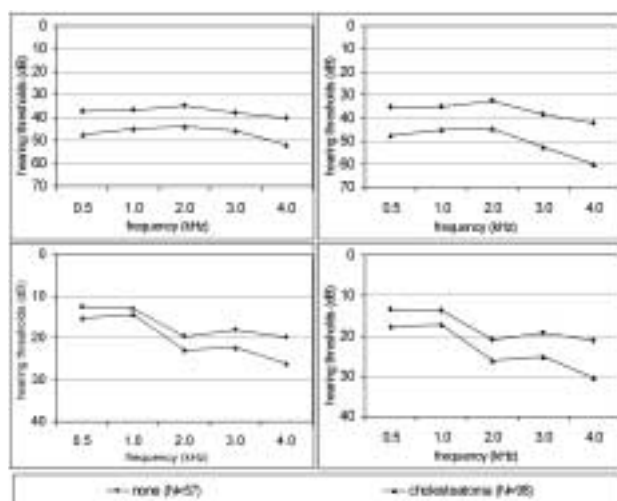


Figure 3: Air conduction before (top left) and after (top right) surgery based on the presence of cholesteatoma. The differences were statistically significant at all the monitored pre-op ($p = 0.001, 0.01, 0.01, 0.04, 0.01$) and post-op frequencies ($p = 0.001, 0.01, 0.002, 0.01, 0.0001$). Bone conduction before (bottom left) and after (bottom right) surgery based on the presence of cholesteatoma. A significant difference was found at a frequency of 4 kHz after surgery ($p < 0.04$).

slight decline in air conduction at 3 and 4 kHz (by 1 to 2 dB). In patients with cholesteatoma, air conduction declined at all frequencies, with a statistical significance at 4 kHz, at which the reduction of air conduction equaled 8 dB ($p = 0.04$).

Bone conduction declined in both groups at all frequencies, and in patients with cholesteatoma, it declined especially at high frequencies (by 3 to 4 dB) (Figure 3b).

4. Hearing thresholds of patients based on ossicular status

In an evaluation of hearing loss based on ossicular status (Figure 4), the best hearing was found in 60 patients with an intact ossicular chain, followed-in a descending order-by 41 patients with a defective incus,

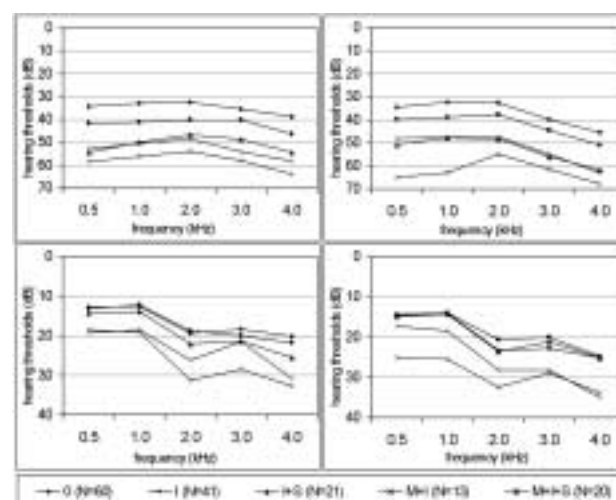


Figure 4. Air conduction before (top left) and after (top right) surgery based on the ossicular status. Statistically significant differences were confirmed between the following groups: a) the group with an intact ossicular chain and that with a defective incus before surgery at frequencies of 0.5 - 2 kHz ($p = 0.03, 0.02, 0.05$), b) the group with an intact ossicular chain and that with a defective incus and stapes at all frequencies before ($p = 0.00001, 0.0002, 0.003, 0.03, 0.02$) and after surgery ($p = 0.005, 0.007, 0.01, 0.02, 0.05$), c) the group with an intact ossicular chain and that with a defective incus and malleus at all frequencies before surgery ($p = 0.001, 0.004, 0.01, 0.02, 0.02$) and at 0.5 and 1 kHz after surgery ($p = 0.05, 0.03$), and d) the group with an intact ossicular chain and that with a defect in all three ossicles at all frequencies before ($p = 0.00000, 0.00001, 0.0001, 0.0009, 0.0004$) and after surgery ($p = 0.00000, 0.00000, 0.001, 0.005, 0.007$). Bone conduction before (bottom left) and after (bottom right) surgery based on the ossicular status. Significant differences were found between the group with an intact ossicular chain and that with a defective malleus and incus at 2 and 4 kHz before ($p = 0.03, 0.02$) and at 1 kHz after surgery ($p = 0.05$) and between the group with an intact ossicular chain and that with a defect in all ossicles at 2 kHz ($p = 0.03$) before and at 0.5 - 2 kHz after surgery ($p = 0.04, 0.03, 0.04$). Abbreviations: O - malleus, incus, and stapes present, I - defect of incus, S - defect of stapes, M - defect of malleus

21 patients with both a defective incus and stapes, and 13 patients with both a defective malleus and incus, while the worst hearing impairment was in 20 patients who had defects in all three ossicles. Statistically significant differences before and after surgery were confirmed between the following patient groups: a) the group with an intact ossicular chain and that with a defective incus, b) the group with an intact ossicular chain and that with a defective incus and stapes, c) the group with an intact ossicular chain and that with a defective incus and malleus, and d) the group with an intact ossicular chain and that with a defect in all three ossicles ($p < 0.05$). A mutual comparison of all the groups did not reveal significant differences. After surgery there was a minor improvement in air conduction in the group with a defective incus (by 2 to 3 dB at 0.5, 1 and 2 kHz) as well as in the group with a defective incus and stapes and in the group with a defective malleus and incus (by 3 to 4 dB at 0.5 and 1 kHz). In all groups, hearing threshold at high

frequencies of 3 and 4 kHz decreased by 3 to 8 dB

A comparison of bone conduction before and after surgery between the group with an intact ossicular chain and that with a defect in the malleus and incus and between the group with an intact ossicular chain and that with a defect in all ossicles revealed a significant difference only at certain frequencies (Figure 4b, $p < 0.05$). In all groups, post-op bone conduction threshold decreased slightly at high frequencies (by 1 to 5 dB).

5. Hearing thresholds of patients based on the presence of middle ear granulation or effusion

Air and bone conduction was lower in 78 patients with middle ear granulation, compared to 77 patients without granulation (Figure 5). The difference in air conduction in both groups ranged, before surgery, from 5 to 7 dB and after surgery, from 4 to 6 dB. At frequencies of 0.5, 1, and 2 kHz, hearing threshold after surgery remained unchanged in the group without granulation; however, it improved by 1 dB in the group

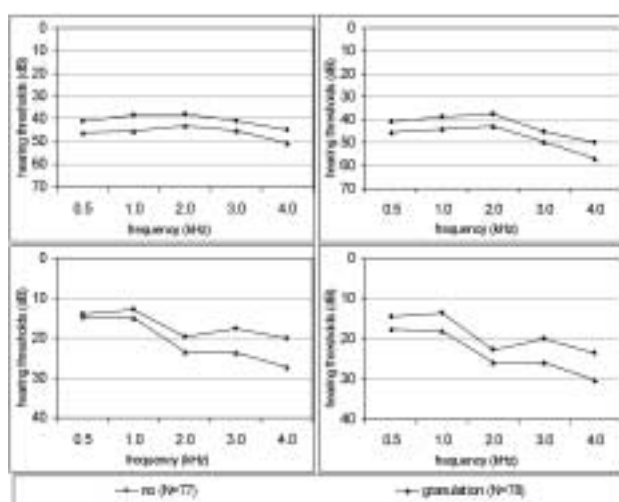


Figure 5. Air conduction before (top left) and after (top right) surgery based on the presence of middle ear granulations or effusion. A statistical difference between both groups was found only before surgery, at 1 kHz ($p = 0.03$). Bone conduction before (bottom left) and after (bottom right) surgery based on the presence of middle ear granulations or effusion. There was no statistical difference.

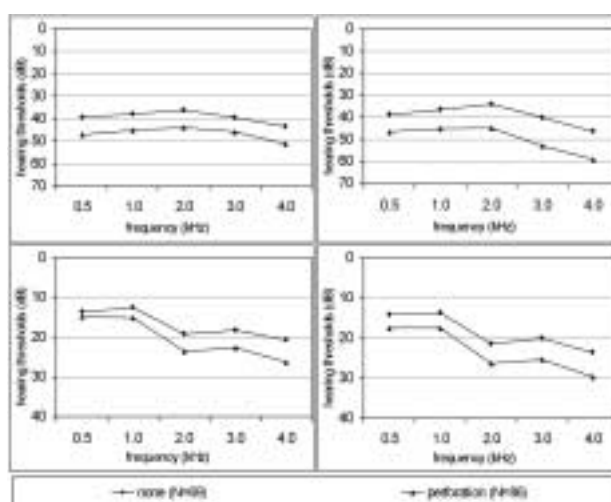


Figure 6: Air conduction before (top left) and after (top right) surgery based on the presence of previous surgery. A significant difference existed at all frequencies between the group with previous surgery and that with revision surgery before ($p = 0.03, 0.03, 0.01, 0.02, 0.03$) and after surgery ($p = 0.001, 0.001, 0.002, 0.01, 0.01$). A comparison of other groups revealed changes only at certain frequencies: between the group with no previous surgery and that with previous surgery at 1 kHz before surgery ($p = 0.04$) and at 0.5 - 2 kHz after surgery ($p = 0.01, 0.03, 0.04$), between the group with no previous surgery and that with revision surgery at 3 kHz before surgery ($p = 0.04$) and at 0.5 - 2 kHz after surgery ($p = 0.02, 0.01, 0.04$). Bone conduction before (bottom left) and after (bottom right) surgery based on previous surgery. Statistical difference was found only between the group with previous surgery and that with revision surgery at 0.5 kHz after surgery ($p = 0.05$).

with granulation. In both groups, post-op hearing threshold at high frequencies of 3 and 4 kHz declined by 4 to 6 dB

6. Hearing thresholds of patients based on previous surgery

An assessment of hearing based on previous surgery (Figure 6) demonstrated that 16 patients with a different type of previous ear surgery had a better hearing threshold than 102 patients without previous surgery or than 37 patients with revision surgery, in whom the lowest air and bone conduction threshold was recorded. A significant difference existed at all air conduction frequencies between the group with previous surgery and that with revision surgery. A comparison of other groups revealed changes only at certain frequencies ($p < 0.05$).

In patients with a different type of previous surgery, air conduction improved post-op at all frequencies (by

1 to 7 dB); in patients without previous surgery, hearing threshold improved at 0.5, 1, and 2 kHz (by a maximum of 2 dB). After surgery, patients with a different type of previous surgery recorded an improvement in bone conduction at 0.5, 1, and 4 kHz (by 2 to 4 dB), while in patients without previous surgery the bone conduction threshold declined by 1 to 3 dB. In patients with revision surgery, air conduction threshold declined at all frequencies (by 2 to 6 dB), and bone conduction threshold declined by 5 to 6 dB.

7. Hearing thresholds of smokers and non-smokers

There were 118 non-smokers and 37 smokers; a comparison of audiometric curves revealed a greater hearing loss in smokers (Figure 7). Post-op, there was a statistically significant difference between the hearing threshold of smokers and non-smokers at 3 kHz and 4 kHz (by 12 dB) ($p < 0.05$).

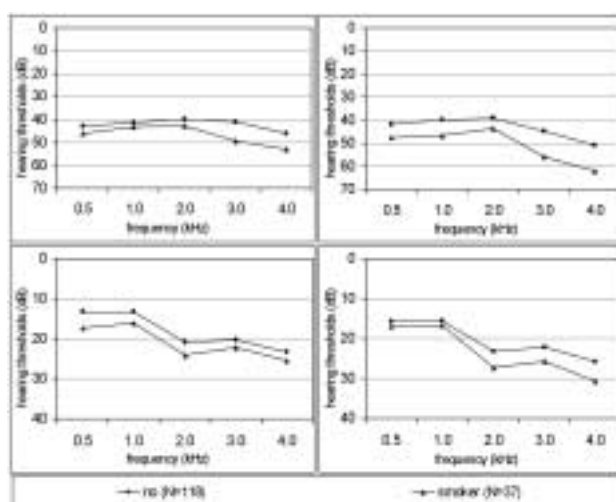


Figure 7: Air conduction before (top left) and after (top right) surgery in smokers and non-smokers. Statistically significant differences were found between the smokers and the non-smokers after surgery at frequencies of 3 and 4 kHz ($p = 0.03, 0.04$). Bone conduction before (bottom left) and after (bottom right) surgery in smokers and non-smokers. There was no statistical difference.

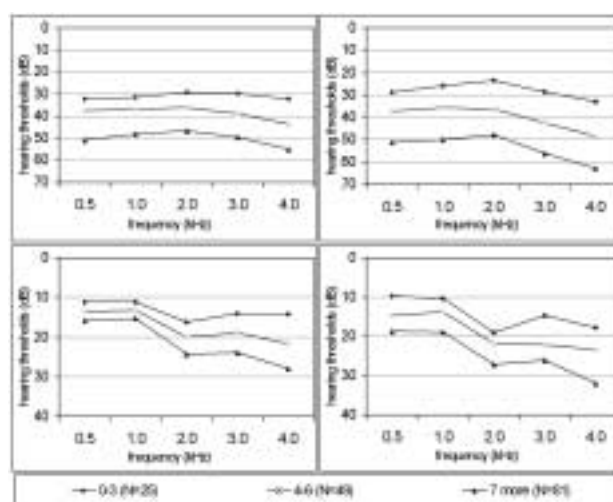


Figure 8: Air conduction before (top left) and after (top right) surgery based on the aggregate MERI. Statistical differences were found between the following groups: a) the group with a MERI of 0-3 and that with a MERI of 4-6 at 4 kHz before surgery ($p = 0.03$) and at 1 - 4 kHz after surgery ($p = 0.03, 0.01, 0.02, 0.02$), b) the group with a MERI of 0-3 and that with a MERI of 7+ at all frequencies before ($p = 0.00001, 0.0001, 0.0002, 0.0004, 0.0001$) and after surgery ($p = 0.00002, 0.00001, 0.00001, 0.00001, 0.00000$), and c) the group with a MERI of 4-6 and that with a MERI of 7+ at all frequencies before ($p = 0.0001, 0.002, 0.006, 0.01, 0.01$) and after surgery ($p = 0.0006, 0.0006, 0.008, 0.004, 0.005$). Bone conduction before (bottom left) and after (bottom right) surgery based on the aggregate MERI. Statistical differences were found between the group with a MERI of 0-3 and that with a MERI of 7+ at 3, and 4 kHz before surgery ($p = 0.04, 0.02$) and at 0.5, 3, and 4 kHz after surgery ($p = 0.05, 0.05, 0.03$).

As for bone conduction, there was no statistically significant difference between smokers and non-smokers, even in a comparison of pre-op and post-op hearing in different groups. Average bone conduction in both groups generally declined, mainly at high frequencies (by 2 to 5 dB).

8. Hearing thresholds based on risk value

Patients with a lower MERI had better pre-op and post-op air and bone conduction than patients with a higher MERI (Figure 8). In 25 patients with a MERI of 0 to 3, there was a post-op improvement in air conduction at frequencies of 0.5 to 3 kHz (by 1 to 6 dB). In a group of 49 patients with a MERI of 4 to 6, there was a decline in air conduction at frequencies of 3 and 4 kHz (by 4 and 5 dB), and in 81 patients with a MERI of 7 or higher, there was a decline in air conduction at all frequencies (by 1 to 7 dB). There was a statistically significant difference between groups based on the sum of the MERI ($p < 0.05$). Post-op bone conduction deteriorated mainly in patients with a higher MERI.

Discussion

Results of treatment of chronic otitis media have been analyzed in numerous publications; however, no uniform criteria for the monitored indicators exist.^[2-6] The main aim of surgery is to remove inflammation and to maintain or permanently improve hearing.

Based on an evaluation of our sample of 155 patients, we noted that after surgery, air conduction was generally preserved or there was an improvement at speech frequencies of 0.5, 1 and 2 kHz. However, at high frequencies (3 and 4 kHz), a significant reduction in the hearing threshold usually occurred. Patients with a perforation of the eardrum had a statistically significant worse hearing compared to patients with an intact eardrum before surgery (at speech frequencies) as well as after surgery (at all frequencies). Statistically, patients with cholesteatoma had a much greater air conduction hearing loss at all frequencies both pre-op and post-op compared to patients without cholesteatoma. Patients with an intact ossicular chain had the best pre-op and post-op hearing; a statistically significant difference was found when this group of

patients was compared to the group suffering from a defective incus and to the group with defects apparent in all ossicles. Air conduction hearing improved post-op in the groups with a defective: a) incus (at 0.5, 1 and 2 kHz), b) incus and stapes (at 0.5 and 1 kHz), and c) malleus and incus (at 0.5, 1 and 2 kHz). In patients undergoing revision surgery, pre-op and post-op air conduction was significantly worse compared to patients who had undergone a different type of ear surgery in the past. A comparison of air conduction after surgery revealed a significant difference at speech frequencies of 0.5, 1 and 2 kHz between all three groups (without previous surgery, with a different type of surgery, and with revision surgery). Smokers had a lower pre-op and post-op hearing threshold; however, a significant difference was found only in post-op air conduction at high frequencies (3 and 4 kHz). Patients with a lower MERI had better pre-op and post-op air and bone conduction than patients with a higher MERI. The aggregate MERI risk value was a good prognostic factor for hearing before and after surgery. No significant difference was found in the comparison of the groups based on the presence of middle ear granulations and otorrhea.

Importantly, a statistically significant difference that is observed only at 4 kHz is less meaningful than a difference observed across several frequencies.

In the Becvarovski and Kartush's study, the following items were considered to be very negative prognostic factors for post-op healing: otorrhea, cholesteatoma, ossicular disorders, middle ear granulations, revision surgery, and smoking.^[5] The authors evaluated the condition of the ear based on post-op otoscopic findings - the presence of perforation of the eardrum or middle ear atelectasis. Our study was based on a comparison of pre-op and post-op hearing and it confirmed that most of these factors had a negative influence on hearing before and after surgery. In contrast to the conclusions of the above authors, middle ear granulation and otorrhea before surgery were not found to have a negative effect on the patients' hearing.

There could certainly be many other factors affecting healing, the condition of the middle ear, and the hearing threshold after surgery for chronic suppurative otitis media, which were not examined in our study. These factors include local aspects (such as the presence of pathogenic micro-organisms, the scope of mastoid pneumatization, and the type of surgery), regional factors (such as the condition of the nasal mucous membrane and the paranasal sinuses), and general factors (such as administration of antibiotics, patient age, diabetes mellitus, general immunity, and the impact of the social environment)^[2,3,8-11]. Systematic monitoring, in prospective studies, of not only the factors that we examined but also of other factors would certainly improve our knowledge of prognostic factors in chronic suppurative otitis media.

Conclusion

The presented evaluations of the hearing threshold before and after surgery in patients with chronic otitis media demonstrate that highly significant negative pre-op prognostic factors include the presence of cholesteatoma, perforation of the eardrum, ossicular status, previous surgery, and the MERI risk value. Furthermore, it was found that smoking was a less significant risk factor. Finally, minor prognostic factors included the presence of middle ear granulations and otorrhea.

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