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# Factors that have an influence on bone conduction thresholds changes after otosurgery in the patients operated on due to the perforation of the tympanic membrane with the preserved ossicular chain

**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:**

**Introduction:** The aim of the middle ear surgery is to eliminate abnormalities from the mucous, ensure the due airing of the postoperative cavity and reconstruct the sound-conducting system in the middle ear. Numerous reports can be found in literature on the changes to bone conduction as a consequence of middle ear surgery.

**Study objective:** The aim of the work is to define the factors that affect bone conduction in the patients operated on due to the perforation of the tympanic membrane with the preserved and normal mobile ossicular chain.

**Material and method:** A prospective analysis of patients operated on due to diseases of the middle ear in 2009–2012 was carried out. The cases of patients operated on for the first time due to chronic otitis media were taken into consideration. The analysis encompassed the patients who had undergone myringoplasty. The patients were divided into several groups taking into account the abnormalities of the mucous observed during otosurgery.

**Results**: A significant improvement of bone conduction was observed in the patients with dry perforation, without other lesions in the middle ear. The appropriate pharmacological treatment before otosurgery in patients with permanent discharge from the ear resulted in significant bone conduction improvement. The elimination of granulation lesions turned out to be a positive factor for the future improvement of the function of the inner ear.

**Conclusions:** The lack of abnormalities on the mucous of the middle ear (e.g. granulation,) and discharge has a positive impact on improvement of bone conduction after myringoplasty. Adhesions in the tympanic cavity, especially in the niche of the round window, have a negative impact on improvement of bone conduction in patients after myringoplasty.

**KEYWORDS:** bone conduction, miryngoplasty, chronic otitis media

## INTRODUCTION

Chronic otitis media is characterized by the presence of a defect in the tympanic membrane, constant or transient discharge from the ear and conductive or mixed hearing loss (with a coexisting sensorineural component). The individual types of the disease differ with respect to mucosa lesions (polyps, adhesions, cholesteatoma, granulation tissue, granuloma), clinical course and tendency to bone destruction resulting in intracranial and/or intratemporal complications. One type of chronic otitis media is simple chronic otitis media. This type is common in both children and adults. Inflammation involves the middle ear mucosa, including the part covering the ossicles, which can lead to their partial destruction [1].

Chronic purulent cholesteatomatous otitis media results in a destruction of surrounding tissues and the infection spreads


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to the mastoid process [2,3]. If not properly treated or left untreated, complications may develop in the temporal bone or even intracranially [4,5,6]. Cholesteatoma is associated with increased levels of bone-destructing enzymes.

Chronic granulomatous otitis media is characterized by the presence of polyps and granulomas in the middle ear. It can lead to complications similar as in cholesteatoma. It is assumed that this type can be the result of an acute and chronic inflammation of the middle ear. It is important to differentiate this condition and a neoplastic growth [7,8].

Chronic otitis media can also be a manifestation of tuberculosis, actinomycosis and other specific infections [9].

The treatment of choice of chronic otitis media is surgical intervention along with individually adjusted pharmacotherapy.

The purpose of surgical intervention is to remove abnormal mucosa, provide appropriate ventilation of the postoperative cavity via the auditory tube and to reconstruct the conductive system of the middle ear. In recent years, the emphasis has been put on preservation or, in the case of open tympanoplasty – reconstruction, of the postero-superior wall of the external auditory meatus in order to protect the middle ear from water.

The research is being conducted in order to optimize surgical treatment and determine the gold standard of managing similar clinical situations.

The indicator of hearing improvement after middle ear surgery is the change in cochlear reserve, which corresponds to the type of tympanoplasty. Regardless of that, there are numerous reports in the literature concerning the change in bone conduction as a result of the operation. It is usually explained by the effect of the conductive system on the middle ear function. This relationship is utilized in the soundbridge middle ear implant – a device applied to the ossicles (on the long crus of the incus) in order to facilitate oscillation of the ossicles in patients with sensorineural hearing loss. It remains unsettled which types of abnormal mucosa of the middle ear affect its function [10].

## AIM OF THE STUDY

The aim of the study was to indicate factors affecting bone conduction in patients undergoing surgery for the perforation of the tympanic membrane with a preserved and normally mobile ossicular chain.

**Tab. I.** Characteristics of patients after myringoplasty with respect to observed abnormalities.

| GROUP | NO OF PATIENTS | PATIENT CHARACTERISTICS |
|---|---|---|
| 1 | 24 | control group – myringoplasty, no discharge, normal mucoa of the middle ear (nonsuppurative perforation) |
| 2 | 27 | myringoplasty, no ossiculopasty, no history of discharge, abnormal mucosa |
| 3 | 38 | myringoplasty, no ossciuloplasty, history of discharge |
| 4 | 34 | myringoplasty, no ossiculoplasty, adhesions of the middle ear |
| 5 | 28 | myringoplasty, no ossiculoplasty, granulomatous tissue of the middle ear |

## MATERIALS AND METHODS

A prospective analysis was conducted on patients undergoing surgery due to middle ear pathology in the years 2009-2012. Patients operated on for the first time for chronic otitis media were considered.

Patients undergoing myringoplasty were included in the study. The patients were divided into several groups with respect to the pathology of the mucosa in the affected ear. Additionally, a group of patients with ear discharge prior to surgery and a reference group of patients with dry perforation of the tympanic membrane and normal mucosa were distinguished (Table 1).

Hearing test was conducted immediately before as well as 6 and 12 months after surgical intervention. In the study, we observed changes in bone conduction as an average for speech frequency (500, 1000, 2000Hz) for each group after myringoplasty.

The results were statistically analyzed. As statistically significant, we assumed $p < 0.05$.

## RESULTS

In the years 2009 - 2012, ear surgery was performed in 457 patients at the Department of Otolaryngology, CM, Jagiellonian University. The youngest patient was 6, and the oldest was 80 years old. Mean age was 40.84. Over the studied period, 293 patients were operated for the first time for chronic otitis media.

The inclusion criteria were met by 151 patients undergoing myringoplasty. The group consisted of 80 females and 71 males. The youngest patient was 22, and the oldest was 66

years old. The mean age was 43.96. The intrameatal access was used in 58.33% of patients, and the retroauricular - in 41.67%.

The most commonly used material for the reconstruction of the tympanic membrane was perichondrium. The fascia of the temporal muscle was used less often. In some cases,

perichondrium was enhanced by the cartilage sampled from the auricle (Fig. 1).

Long-term outcomes of surgical treatment were assessed with respect to mean bone conduction difference between the groups. The assessment was conducted before initiating treatment (time 0) and after 6 and 12 months of observation respectively.

For further analysis, we adopted the following abbreviations:

- X = Mean bone conduction value
- X 0 = Mean bone conduction value before treatment
- X 6 = Mean bone conduction value after 6 months of observation
- X 12 = Mean bone conduction value after 12 months of observation
- SD = Standard deviation

A. On variance analysis, the results shown in Table 2 were obtained before surgery ($p < 0.05$):

The results indicate that the mean bone conduction values were statistically similar before treatment (time - 0 months)

B. On variance analysis of mean bone conduction values 6 months following the surgical intervention, the following results were obtained ($p < 0.05$) (Tab. 3):

Based on the statistical analysis of the results, it can be concluded that the mean cochlear reserve values 6 months following the surgical treatment were statistically equal ($p < 0.05$).

C. On variance analysis 12 months following the surgical intervention, the following results were obtained ($p < 0.05$) (Tab. 4):

Between the mean cochlear reserve values, no statistically significant differences were noted.

There was also a tendency for improved bone conduction in audiometry, however, it was not statistically significant in all studied groups.

On variance analysis of the results with regard to time, the answer was searched to the question whether the observed

**Tab. II.** Mean bone conduction values before treatment in respective groups.

| GROUP | X 0 | SD 0 |
|---|---|---|
| 1 | 28,54 | 12,72 |
| 2 | 27,43 | 15,36 |
| 3 | 23,50 | 11,20 |
| 4 | 25,63 | 16,72 |
| 5 | 21,19 | 7,88 |

**Tab. III.** Mean bone conduction values 6 months after surgical treatment in respective groups.

| GROUP | X 6 | SD 6 |
|---|---|---|
| 1 | 18,40 | 11,94 |
| 2 | 20,80 | 14,26 |
| 3 | 16,97 | 10,31 |
| 4 | 23,13 | 14,79 |
| 5 | 16,19 | 7,29 |

change in mean bone conduction within each group after 6 and 12 months respectively was statistically significant.

The observation applied to the mean bone conduction in each group (Tab. 5).
The following abbreviations were adopted:

- X gr. „i" = mean bone conduction in group 'i', where 'i' designates the studied group (1 - 5)
- SD gr. „i" = standard deviation of mean bone conduction in group 'i', where 'i' designates the studied group (1 - 5)

In the control group (group 1), a statistically significant change in the mean bone conduction was noted. Mean bone conduction after 12 months was significantly lower than the mean bone conduction before surgery and it was statistically equal to bone conduction 6 months after surgery. Mean bone conduction after 6 months was significantly lower than the mean before treatment.

On 6-month and 12-month follow-up, no statistically significant change in mean bone conduction was noted in group 2. This group was characterized by anomalies typical for simple chronic otitis media. The removal of hypertrophic mucosa of the middle ear and following myringlopasty did not cause any significant change in mean bone conduction assessed on consecutive follow-up visits after surgical intervention.

In group 3, where the leading symptom was ear discharge reported preoperatively, the change in mean bone conduction was statistically significant. An improvement (decreased mean bone conduction value) was observed after 6 months and it persisted at 12 months postoperatively. Mean bone conduction measured after 6 months was statistically equal to mean bone conduction after 12 months.

The removal of adhesions from the tympanic cavity with intact ossicles in patients from group 4 did not cause a statistically significant change in mean bone conduction on consecutive follow-up visits after surgery.

In patients without ossiculoplasty, with granulomatous tissue (group 5), a statistically significant change in mean bone conduction was observed.

## DISCUSSION

Many authors point to myringoplasty as the hearing-improving procedure. The cited data are backed up by long-term observation and they confirm hearing improvement even in 70 – 90% of patients regardless of the perforation size and type of material used for reconstruction [11,12,13].

In the studied group, the periosteum was the material used for reconstruction in 70% of cases, and in 18 patients it was supported by cartilage. In the rest of the cases, the fascia of the temporal muscle was used.

The debate on the advantages of using fascia or periosteum for tympanic membrane reconstruction is still open. In the literature, there are many articles indicating the advantage of one of the materials over the other or recommending other solutions for myringoplasty [14,15].

Preservation of all ossicles after removing all abnormal mucosa from the tympanic cavity makes the optimal condition for hearing improvement. It is in accordance with the world literature, where it was reported that a significant hearing improvement was observed in most patients with mean cochlear reserve less than 20dB following type I tympanoplasty [16].

With regard to the hearing improvement after middle ear surgery, changes in cochlear reserve, especially in the speech frequency (500-3000Hz), are considered. It should be remembered that the reconstruction of the conductive system of the middle ear influences the inner ear function as well.

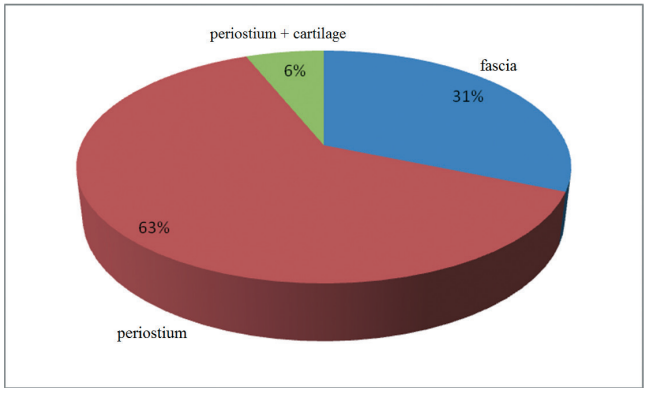


**Fig. 1.** Materials used for reconstruction of tympanic membrane.

**Tab. IV.** Mean bone conduction values 12 months after surgical treatment in respective groups.

| GROUP | X 12 | SD 12 |
|---|---|---|
| 1 | 20,69 | 11,37 |
| 2 | 20,86 | 11,28 |
| 3 | 18,11 | 10,62 |
| 4 | 22,35 | 13,89 |
| 5 | 15,71 | 6,53 |

The influence of the middle ear surgery on the inner ear function has been discussed for a long time. In the study by Vartiainen et al. on 181 patients undergoing surgery for chronic otitis media, it was established that the bone conduction did not change after surgical treatment in 92% of patients, while 5% demonstrated improvement and in 3% the condition worsened. The improvement within the range from 11 dB to 25 dB was observed after removal of advanced abnormal lesions from the tympanic cavity. The average improvement of bone conduction was observed in less than 10% of patients treated for chronic otitis media [17,18].

Many researchers searched for a link between the intensity of the disease and its influence on the inner ear, expressed as a raised bone conduction threshold. Numerous studies prove that such relationship undoubtedly exists [19]. Important observations were made in patients with middle ear mucosal abnormalities (advanced cholesteatoma) or ossicular damage. The previously mentioned factors seem to indirectly impair the inner ear function by influencing the mechanics of the ossicles. An example to illustrate this statement is the case of bone conduction impairment in response to stapes ankylosis in the course of otosclerosis described by Carhart in 1958 [20,21].

**Tab. V.** Mean bone conduction values at the time of surgery and after 6 and 12 months respectively.

| TIME (MONTHS) | X GR. 1 | SD GR. 1 | X GR. 2 | SD GR. 2 | X GR. 3 | SD GR. 3 | X GR. 4 | SD GR. 4 | X GR. 5 | SD GR. 5 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 28,54 | 12,72 | 27,43 | 15,36 | 23,50 | 11,20 | 25,63 | 16,72 | 21,19 | 7,88 |
| 6 | 18,40 | 11,94 | 20,80 | 14,26 | 16,97 | 10,31 | 23,13 | 14,79 | 16,19 | 7,29 |
| 12 | 20,69 | 11,37 | 20,86 | 11,28 | 18,11 | 10,62 | 22,35 | 13,89 | 15,71 | 6,53 |

It was attempted to explain the impairment of bone conduction by a toxic effect of mediators of inflammation in the middle ear on the inner ear function. The possibility of biochemical changes in the perilymph and endolymph is emphasized, by means of substance penetration from the middle ear through the round window.

The previously mentioned mechanical and biochemical factors often act simultaneously. It is thought that bone conduction impairment in chronic otitis media may be induced by chronic inflammation, it can be iatrogenic in origin as a result of maneuvers applied to the ossicular chain, or results from noise associated with opening the temporal bone [22].

The mean bone conduction values were measured before surgical treatment and after 6 and 12 months of observation respectively. For all time periods, normal or normal-like distribution was obtained, which is the necessary condition to apply statistical analysis.

A significant improvement of bone conduction was observed in patients in the control group with dry perforation and no other lesions of the middle ear. The closure of the defect significantly improved the bone conduction, which was observed after 6 months and persisted during the 12-month observation. The extent of treatment in this group restored the most physiological relationship between the middle ear mechanics and the inner ear function.

In patients with ear discharge preoperatively, the appropriate pharmacotherapy preceding tympanic membrane reconstruction leading to 'the dry ear' resulted in bone conduction improvement similar to the control group.

A negative influence of lesions surrounding the round window on bone conduction is known [22,23,24]. The analysis of patients treated at the Department of Otolaryngology, CM, Jagiellonian University confirms those findings. In patients with adhesions within the tympanic membrane, no statistically significant improvement in bone conduction was observed following surgical intervention. This observation can be explained by the tendency to limited mobility of the ossicles caused by even partial restoration of adhesions after surgery. The greatest risk of worsening bone conduction is seen in the case of adhesions located in the round window.

The removal of granulation tissue proved to be a positive prognostic factor for improvement of the inner ear function. In such cases, not only was the abnormal mucosa removed during the surgery, but also the toxic effect of inflammatory mediators on the inner ear function was eliminated. In this group, no improvement was observed in terms of the cochlear reserve change due to the fact that the postoperative hearing improvement was not statistically significant.

Searching for factors influencing hearing improvement in patients undergoing myringloplasty, no significant improvement was observed only in the case of the granulation tissue present in the tympanic cavity with unaffected ossicular chain. In other groups without ossiculoplasty (no discharge, suppurative, with adhesions), the hearing improvement (manifesting itself as a closed cochlear reserve) was statistically significant. Those observations are in accordance with the reports in the world literature [25,26].

## CONCLUSIONS:

1. The lack of abnormal middle ear mucosa is a positive prognostic factor with respect to bone conduction improvement following myringlopasty.

2. The above statement is also true for patients with preoperative ear discharge that has been controlled by proper preoperative pharmacotherapy.

3. Adhesions within the tympanic cavity, especially in the round window, are a negative prognostic factor with respect to bone conduction improvement following myringoplasty.

4. Removal of granulation tissue from the tympanic cavity has a beneficial influence on the inner ear function measured by bone conduction value.

## REFERENCES


1. Schuknecht H.F.: Pathology of the ear. Lea&Febiger. Philadelphia,1993.
2. Sudhoff H., Dazert S., Gonzales A.M. et al.: Angiogenesis and angiogenic growth factors in middle ear cholesteatoma. Am. J. Otol. 2000; 21 (6): 793–798.
3. Sudhoff H., Hildmann H.: Current theories on the origin of cholesteatoma. HNO. 2003; 51 (1): 71–82.
4. Kuczkowski J., Narozny W., Mikaszewski B.: Otogenic complications in children. J. Paediatr. Child Health. 2004; 40 (7): 414–415.
5. Majmundar K., Shaw T., Sismanis A.: Traumatic cholesteatoma presenting as a brain abscess: a case report. Otol. Neurotol. 2005; 26 (1): 65–67.
6. Niemczyk K., Marchel A., Bruzgielewicz A. et al.: Treatment of petrosal cholesteatoma with intracranial extention. Otolaryngol. Pol. 2004; 58 (5): 907–913.
7. Wiatr M., Składzień J., Tomik J.: Przewlekłe zapalenie ucha środkowego jako wstęp do usznopochodnych powikłań wewnątrzczaszkowych. Otolaryngol. Pol. 2008; 1: 49–53.
8. Manolidis S.: Dural herniations, encephaloceles: an index of neglected chronic otitis media and further complications. Am. J. Otolaryngol. 2002; 23 (4): 203–208.
9. Składzień J., Trąbka-Zawicki P., Wierzchowski W. et al.: Actinomycosis of the middle ear. Otolaryngol. Pol. 2002; 56 (3): 369–371.
10. Wiatr M., Skladzien J., Tomik J. et al.: Relationship Between Bone Conduction Thresholds and Hearing Results After ear Surgery. J. Int. Adv. Otology. 2011;7 (1): 82–86.
11. Karela M., Berry S., Watkins A. et al.: Myringoplasty: surgical outcomes and hearing improvement: is it worth performing to improve hearing? Eur. Arch. Otorhinolaryngol. 2008 Jan 15.
12. Frade G.C., Castro V.C., Cabanas R.E. et al.: Prognostic factors influencing anatomic and functional outcome in myringoplasty. Acta Otorrinolaringol. Esp. 2002; 53 (10): 729–735.
13. Wiatr M., Wiatr A., Składzień J., Stręk P.: Determinants of Change in Air-Bone Gap and Bone Conduction in Patients Operated on for Chronic Otitis Media. Med. Sci. Monit. 2015; 21: 2345–2351.
14. Gierek T., Slaska-Kaspera A., Majzel K. et al.: Results of myringoplasty and type I tympanoplasty with the use of fascia, cartilage and perichondrium grafts. Otolaryngol. Pol. 2004; 58 (3): 529–533.
15. Fishman A.J., Marrinan M.S., Huang T.C. et al.: Total tympanic membrane reconstruction: AlloDerm versus temporalis fascia. Otolaryngol. Head Neck Surg. 2005; 132 (6): 906–915.
16. Maani T., Lo S., Knight J.: Endaural or postaural incision for myringoplasty: does it make a difference to the patient? Clin. Otolaryngol. 2005; 30 (1): 78.
17. El-Sayed Y.: Bone Conduction Impairment in Uncomplicated Chronic Suppurative Otitis Media. Am. J. Otolaryngol. 1998; 19 (3): 149–153.
18. Linstrom C.J., Rosen A., Silverman C.A. et al.: Bone conduction impairment in chronic ear disease. Ann. Oto. Rhino. Laryngol. 2001; 110 (5): 437–440.
19. Berenholz L.P., Lippy W.H., Burkey J.M. et al.: Stapedectomy following tympanoplasty. J. Laryngol. Otol. 2001; 115 (6): 444–446.
20. Koike T., Murakoshi M., Hamanishi S. et al.: An apparatus for diagnosis of ossicular chain mobility in humans. Int. J. Audiol. 2006; 45 (2): 121–128.
21. Vartiainen E., Vartiainen J.: Age and hearing function in patiens with chgronic otitis media. J. Otolaryngol. 1995; 24 (6): 336–339.
22. Linstrom C.J., Silverman C.A., Rosen A. et al.: Bone conduction impairment in chronic ear disease. Ann. Otol. Rhinol. Laryngol. 2001; 110: 437–441.
23. Teufert K.B., De La Cruz A.: Tympanosclerosis: long-term hearing results after ossicular reconstruction. Otolaryngol. Head Neck Surg. 2002; 126 (3): 264–272.
24. Tos M., Lau T.: Hearing after surgery for cholesteatoma using various techniques.Auris Nasus Larynx. 1989; 16 (2): 61–73.
25. Jeng F.C., Tsai M.H., Brown C.J.: Relationship of preoperative findings and ossicular discontinuity in chronic otitis media. Otol. Neurotol. 2003; 24 (1): 29–32.
26. Niemczyk K., Nitek S., Wysocki J. et al.: Anatomy of sinus tympani. Otolaryngol. Pol. 2003; 57 (3): 389–393.


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