

Received: 2015.03.12  
Accepted: 2015.05.04  
Published: 2015.08.11

# Determinants of Change in Air-Bone Gap and Bone Conduction in Patients Operated on for Chronic Otitis Media

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

ACEG **Maciej Wiatr**  
BE **Agnieszka Wiatr**  
DF **Jacek Składzień**  
DE **Paweł Stręk**

Department of Otolaryngology, Head and Neck Surgery, Jagiellonian University, Cracow, Poland

**Corresponding Author:** Maciej Wiatr, e-mail: [mwiatr@mp.pl](mailto:mwiatr@mp.pl)  
**Source of support:** Departmental sources

**Background:** Middle ear surgery aims to eliminate pathology from the middle ear, improve drainage and ventilation of the postoperative cavity, and reconstruct the tympanic membrane and ossicles.

The aim of this work is to define the factors that affect ABG (air-bone gap) and bone conduction in the patients operated on due to chronic otitis media.

**Material/Methods:** A prospective analysis of patients operated on due to diseases of the middle ear during 2009–2012 was carried out. The cases of patients operated on for the first time due to chronic otitis media were analyzed.

The analysis encompassed patients who had undergone middle ear surgery. The patients were divided into several groups taking into account the abnormalities of the middle ear mucous and damage of the ossicular chain observed during otosurgery.

**Results:** A significant hearing improvement was observed in patients with type 2 tympanoplasty in the course of chronic cholesteatoma otitis media and in patients with simple chronic inflammatory process in whom a PORP was used in the reconstruction. Granulation tissue was an unfavorable factor of hearing improvement following tympanoplasty.

A significant improvement of bone conduction was observed in the patients with dry perforation without other lesions in the middle ear.

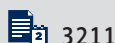
The elimination of granulation lesions was a positive factor for the future improvement of the function of the inner ear.

**Conclusions:** The presence of granuloma-related lesions in the middle ear spaces is likely to impede hearing improvement. Damage to the ossicular chain rules out the possibility of bone conduction improvement after surgery.

The prognosis on tube-related simple chronic otitis media after myringoplasty, with the preserved continuity of the ossicular chain, consists of closing the ABG and leads to significant improvement of bone conduction.

**MeSH Keywords:** **Bone Conduction • Hearing Loss, Conductive • Ossicular Prosthesis • Otitis Media**

**Full-text PDF:** <http://www.medscimonit.com/abstract/index/idArt/894087>



## Background

Chronic otitis media is characterized by a defect to the tympanic membrane, conductive hearing loss (or mixed hearing loss where the concurrent sensorineural component is involved), and permanent or periodical discharge from the ear. Depending on the character of lesions to the middle ear mucous, different types of this abnormality are distinguished: simple chronic otitis media, chronic cholesteatoma otitis media, chronic granulomatous otitis media, and chronic otitis media associated with specific diseases. Particularly notable is the occurrence of cholesteatoma and granulation tissue, which are characterized by a tendency to damage the bone tissue, implying the risk of otogenic intracranial and intratemporal complications (Figure 1) [1–3].

The treatment of choice is surgery aimed at the elimination of abnormalities from the middle ear, the generation of dry and duly aired postoperative cavity, and hearing improvement. An important component of the methodology of surgical treatment consists in the preservation of the upper posterior wall of the external auditory meatus in order to protect the region of the middle ear from contacting the external environment. In the case of canal wall-down tympanoplasty, a search for methods enabling the reconstruction of the upper posterior wall of the external auditory meatus has been underway. The aim of non-invasive treatment in the course of chronic otitis media is to ensure supplementary treatment in the form of individually selected pharmacotherapy in order to obtain the so-called dry ear during the preoperative period or to eliminate the discharge from the ear occurring periodically in the aftermath of canal wall-down tympanoplasty [4,5].

Hearing improvement after otosurgery is measured by the degree of closure of the Air-Bone Gap (the shift in air conduction threshold level compared to bone conduction threshold level) in pure tone audiometry (PTA). Attention is also paid to the shift in bone conduction threshold level after middle ear surgery. The above interrelationship is exemplified by the occurrence of the Carhart sign in the patients operated on due to otosclerosis. That regularity is claimed to be due to the impact



**Figure 1.** The cholesteatoma in scanning electron microscopy.

of the conductive mechanism of the middle ear on the function of the inner ear [6,7].

The aim of the research is to define the determinants of hearing improvement in the patients with chronic otitis media in terms of ABG (Air-Bone Gap) closure and a change in bone conduction after surgery.

## Material and Methods

The research consisted in a prospective analysis of the patients operated on due to the diseases of the middle ear during the period of 2009–2012. Patients operated on for the first time due to chronic otitis media were considered for inclusion. A questionnaire was devised that described the conditions reported by the patient during the preoperative stage, the abnormalities observed in the middle ear during the surgery, the method applied to reconstruct the sound-conducting system in the middle ear, and the observations made during follow-up examinations.

We distinguished between patients in whom the treatment had involved only myringoplasty and those in whom the reconstruction of the ossicular chain had also been required. The patients classified into the above groups were further divided into subgroups according to inner ear mucous abnormalities observed during surgery (Table 1).

Hearing test was carried out immediately before surgery and at 6 and 12 months after otosurgery. The analysis pertained to the changes to ABG and bone conduction thresholds expressed as the average values for the frequency of speech (500, 1000, 2000Hz) for each group of patients with myringoplasty and ossiculoplasty.

The results were subject to statistical analysis. Statistically significant results were given for  $p < 0.05$ .

All the experiments reported in this manuscript were conducted in accordance with the recommendations of IASP and the NIH Guide for the Care and Use of Laboratory Animals and were reviewed and accepted by the Local Bioethics Committee.

All participants gave written informed consent to take part in this study.

## Results

In 2009–2012, 457 patients underwent otosurgery at the Otolaryngology Teaching Hospital of Collegium Medicum, Jagiellonian University. The youngest patient in the group under

**Table 1.** Characteristics of analyzed patients with chronic otitis media.

Group no.	Number of patients	Characteristics of patients who underwent surgery
<b>Patients with myringoplasty depending on the type of observed abnormalities (151 patients)</b>		
Group 1	24	Control group – myringoplasty, w/o discharge, normal mucous in the region of the middle ear (dry perforation)
Group 2	27	Myringoplasty, w/o ossiculoplasty, w/o discharge in medical history but with abnormal mucous (dry perforation with intact ossicular chain)
Group 3	38	Myringoplasty, w/o ossiculoplasty, with discharge in medical history (intact ossicular chain, recurrent discharge)
Group 4	34	Myringoplasty, w/o ossiculoplasty, adhesions in the region of the middle ear
Group 5	28	Myringoplasty, w/o ossiculoplasty, granulation tissue in the region of the middle ear
<b>Patients with ossiculoplasty (142 patients)</b>		
Group 6	24	Ossiculoplasty, remodeled own ossicle (malleus or incus) put on intact stapes; cholesteatoma
Group 7	22	Ossiculoplasty, remodeled own ossicle (malleus or incus) put on intact stapes; granulation
Group 8	32	Ossiculoplasty, tympanic membrane graft put onto the normal stapes
Group 9	38	Ossiculoplasty, tympanic membrane graft onto the plate of the stapes (a palisade of cartilage strips between the plate of the stapes and the tympanic membrane graft)
Group 10	26	Ossiculoplasty, porp put on intact stapes

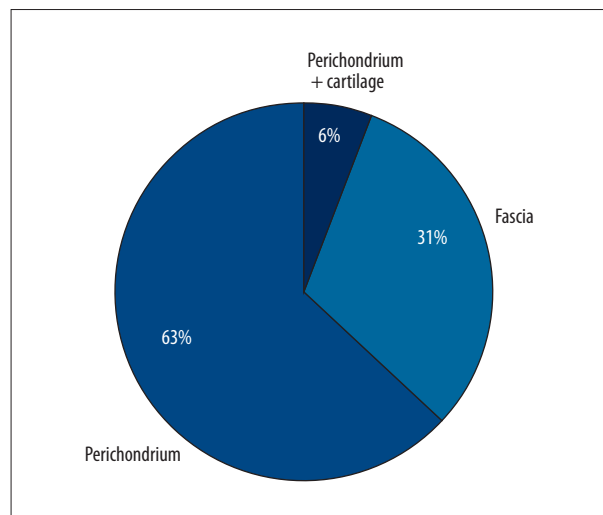
discussion was 6 years old and the oldest was 80. The average age was 40.84 years. In the analyzed time span, 293 patients were operated on due to chronic otitis media for the first time.

There were 151 successive patients with myringoplasty and 142 patients in whom ossiculoplasty had been performed who met the inclusion criteria. That group comprised 160 women and 133 men. The youngest patient was 22 and the oldest was 66. The average age was 43.96 years. In 58.33% of the cases, the surgery was performed from endaural approach, and in 41.67% from retroauricular approach.

The perichondrium was the most common material used for the reconstruction of the tympanic membrane. The temporal fascia was used less often. In a few cases, the perichondrium was strengthened with cartilage extracted from the tragus (Figure 2).

Distant results of the surgery were analyzed from the aspect of the change of the average bone conduction values between the groups. The assessment was made prior to the commencement of the treatment (time 0) and after 6 and 12 months of follow-up.

The analysis of variance of the obtained results in relation to the passing of time was carried out with a view to determining whether the observed change of the average value of ABG within each of the groups after 6 and 12 months of follow-up was statistically significant.



**Figure 2.** Materials used for the reconstruction of the tympanic membrane.

The observation was concerned with the behavior of the average value of cochlear reserve within the particular groups (Tables 2, 3).

The following abbreviations were used in the study:  
 X gr. “i” = the average ABG in group “i”,  
 where “i” stands for the number of the analyzed group (1–10)  
 SD gr. “i” = standard deviation in the average ABG in group “i”,  
 where “i” stands for the number of the analyzed group (1–10)

**Table 2.** Average ABGs observed within groups with myringoplasty before surgery and after 6 and 12 months of follow-up.

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	24.77	13.96	27.61	13.24	25.00	11.76	27.30	11.62	25.12	12.48
6	20.69	9.94	20.80	12.03	20.48	9.14	19.21	8.54	19.88	12.98
12	17.83	11.64	19.74	12.37	18.02	9.76	20.49	10.22	16.90	10.04

**Table 3.** Average ABGs observed within groups with ossiculoplasty (no. 6, 7, 8, 9 and 10) before surgery and after 6 and 12 months of follow-up.

Time (months)	X gr. 6	SD gr. 6	X gr. 7	SD gr. 7	X gr. 8	SD gr. 8	X gr. 9	SD gr. 9	X gr. 10	SD gr. 10
0	31.87	10.58	27.35	9.37	32.08	10.32	38.68	10.36	33.28	11.25
6	19.79	6.23	26.51	10.79	26.77	10.76	35.26	9.77	25.98	6.83
12	19.31	7.33	27.35	12.63	25.10	10.99	35.44	14.35	25.33	7.39

Within the control group (group 1), statistically significant changes of the average ABG were not observed. The group had the fewest abnormalities of the middle ear, which resulted in the lack of any significant variations of the average value of cochlear reserves tested during the follow-up examinations.

The follow-up after 6 and 12 months from otosurgery in group 2 revealed some statistically significant changes of the average value of ABG ( $p=0.05$ ). The average value of ABG observed after 12 months was significantly lower than the average value of ABG measured before the surgery and statistically equal to the average value of ABG tested after 6 months from the surgery. The average value of ABG after 6 months was significantly lower than the average value of ABG prior to the commencement of the treatment. The patients in that group did not report discharge from the ear during preoperative examination; however, due to the occurrence of other lesions within the region of the middle ear, the surgical treatment and its accompanying elimination of abnormalities to the middle ear mucous brought about significant hearing improvement, which was observed at 6- and 12-month follow-ups.

In group 3, in which discharge from the ear reported during the preoperative period was the predominant symptom, the change of the average value of ABG was statistically significant. An improvement (ie, a decrease in the average value of ABG) was observed after 6 months, and that improved condition was retained after 12 months. The average value of ABG measured after 6 months was statistically equal to the average value of ABG after 12 months.

The removal of adhesions from the tympanic cavity with undamaged ossicular chain in the patients from group 4 also yielded some statistically significant differences between the average values of ABG observed during the successive follow-up examinations. The average value of ABG measured after 6 months was statistically equal to the average value of ABG after 12 months. The decrease in the average value of ABG observed after 6 and 12 months testifies to the effectiveness of the treatment and the retention of improved hearing over a long follow-up period.

In the patients without ossiculoplasty and with granulation tissue (group 5), statistically significant changes of the average value of ABG were not observed during follow-up examinations. The above observation points to the fact that granulomatous lesions are likely to impede hearing improvement in the future, even if the continuity of the ossicular chain is preserved.

Statistically significant lesions testifying to the effectiveness of the treatment were observed within group 6. The average value of ABG after 12 months was smaller than the average value of ABG at the beginning of the treatment and statistically equal to the average value of ABG after 6 months, while the average value of ABG after 6 months was significantly smaller than the average value of ABG at the beginning of the treatment. In accordance with the philosophy behind ossiculoplasty, the removal of cholesteatoma lesions and successive type 2 tympanoplasty yielded satisfactory results in the form of hearing improvement.

In group 7, significant changes (i.e., the closure of the average value of ABG) were not observed with the passing of time.

**Table 4.** The average values of bone conduction in the groups with myringoplasty on the day of the surgery and after 6 and 12 months from the surgery.

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

**Table 5.** The average values of bone conduction in the groups with ossiculoplasty on the day of the surgery and after 6 and 12 months from the surgery.

Time (months)	X gr. 6	SD gr. 6	X gr. 7	SD gr. 7	X gr. 8	SD gr. 8	X gr. 9	SD gr. 9	X gr. 10	SD gr. 10
0	27.57	19.07	30.07	13.80	34.58	19.03	25.35	10.97	29.74	13.14
6	26.74	17.30	24.77	12.37	34.27	16.87	23.42	13.09	29.74	14.43
12	26.04	16.61	26.43	13.93	35.62	16.59	23.59	12.43	25.25	14.16

The group comprised the patients with damage to the ossicular chain in whom abnormalities other than cholesteatoma occurred in the middle ear. In spite of reconstruction similar to the one performed in the patients with cholesteatoma (group 5), significant hearing improvement was not observed.

In the patients classified as group 8, statistically significant changes of the average value of ABG were not observed during follow-up examinations carried out after 6 and 12 months from the surgery.

In group 9, significant change of the average value of ABG was not observed, showing that hearing quality did not improve by 6 and 12 months after surgery.

The results observed in the patients classified as groups 8 and 9 confirm unambiguously that a significant damage to the ossicular chain, with only the stapes (particularly the base) being preserved often implies that hearing quality does not improve after middle ear surgery. In these patients the priority for surgical treatment is in the radical elimination of lesions and obtaining “dry ear”.

The use of a ventilation tube (group 10) to restore the continuity of the ossicular chain brought about a statistically significant change of the average value of ABG ( $p=0.046$ ) by 6 months after otosurgery, showing the utility of using that material as a PORP in selected cases. A comparison of the results obtained 6 and 12 months after otosurgery did not reveal any significant changes, showing that the obtained degree of hearing improvement was retained at follow-up examinations.

On the successive stage of hearing quality tests in patients who had undergone otosurgery, which consisted in an analysis of variance of the obtained results in reference to the passage of time, the question was whether the observed change of the average value of bone conduction within each of the groups after 6 and 12 months of follow-up was statistically significant.

The observation was concerned with the behavior of the average value of bone conduction within each group (Tables 4, 5).

The following abbreviations are used:

X gr. “i” = the average value of bone conduction in group “i” where “i” stands for the number of the analyzed group (1–10)  
SD gr. “i” = standard deviation of the average value of bone conduction in group “i” where “i” stands for the number of the analyzed group (1–10)

Within the control group (group 1), statistically significant changes of the average bone conduction were observed. The average value of bone conduction observed after 12 months was significantly lower than the average value of bone conduction measured before the surgery and statistically equal to the average value of bone conduction tested after 6 months from the surgery. The average value of bone conduction after 6 months was significantly lower than the average value of bone conduction prior to the commencement of the treatment.

The follow-up at 6 and 12 months after otosurgery in group 2 did not reveal any statistically significant changes of the average value of bone conduction. This group was characterized by abnormalities typical of simple chronic otitis media. The

elimination of proliferative lesions from the middle ear mucous and the subsequent myringoplasty did not bring about significant changes of the average values of bone conduction tested at follow-up examinations.

In group 3, in which discharge from the ear reported during the preoperative period was the predominant symptom, the change of the average value of bone conduction was statistically significant. An improvement (i.e., a decrease in the average value of bone conduction) was observed after 6 months, and that improved condition was retained after 12 months. The average value of bone conduction measured after 6 months was statistically equal to the average value of bone conduction after 12 months.

The removal of adhesions from the tympanic cavity with undamaged ossicular chain in the patients from group 4 did not yield any statistically significant differences between the average values of bone conduction observed during the successive follow-up examinations.

In the patients without ossiculoplasty and with granulation tissue (group 5), a statistically significant change of the average values of bone conduction was observed.

In the groups in which damage to the ossicular chain occurred (groups 6–10), regardless of the method used to reconstruct the sound-conducting system in the middle ear, statistically significant changes to the value of bone conduction within the range of the frequency of speech were not observed.

## Discussion

The basic aim of the surgical treatment of conditions of the middle ear is to eliminate abnormalities from the mucous of the middle ear, which is followed by ensuring the function of the auditory tube, while the final stage is the reconstruction of the sound-conducting system in the middle ear. The above principles are fulfilled parallel to the attempts to preserve the upper posterior wall of the external auditory meatus to protect the region of the middle ear from direct contact with the external environment.

The preservation of all the ossicles after the coexistent abnormalities of the tympanic membrane have been eliminated offers the optimum conditions for hearing improvement. This observation is in line with the reports from reference literature from across the world that a significant hearing improvement was observed in the majority of patients with the average ABG closure below 20 dB who underwent type 1 tympanoplasty [8]. The observation of the behavior of the average values of ABG in each of the groups confirmed that hearing

quality had improved significantly in the patients from the groups *without ossiculoplasty* (including the control group), but also in the patients in whom it had been feasible to perform type II tympanoplasty (the placing of the modelled incus on the normal stapes), and in those from group 10, where the ossicular chain had been reconstructed with the use of a PORP (partial ossicular replacement prosthesis placed on the head of the stapes) [9–11].

According to information contained in reference literature, obtaining normal suprastructure of the stapes after abnormalities were removed, and the reconstruction of the ossicular chain by placing the patient's own modelled ossicle on the head of the stapes, results in hearing improvement in nearly a half of cases [12,13]. The hearing improvement in the analyzed patients was significantly better in the group with cholesteatoma than in the cases of similar damage to the ossicular chain and the co-occurrence of other lesions on the mucous of the middle ear. This observation corresponds with the reports by other authors, especially in terms of the unfavorable effect of cholesteatoma-related lesions in the middle ear on the improvement of hearing quality [14,15].

The tests carried out by Vartiainen et al. showed that in the group of 181 patients who had undergone surgery due to chronic otitis media, the value of bone conduction did not change after the surgical treatment in 92%, while an improvement was observed in 5%, and deterioration in 3%.

Significant observations have been made with regard to patients with lesions on the mucous of the middle ear (advanced cholesteatoma) or damage to the ossicles. By affecting the mechanics of the ossicular chain, the above factors seem to have an indirect effect on the function of the inner ear. The veracity of that statement is shown by the case of bone conduction disorder in response to the ankylosis of the stapes in the course of otosclerosis described by Carhart in 1958 [16,17].

Attempts have also been made to explain bone conduction disorder as resulting from the toxic effect of mediators of inflammation in the middle ear on the function of the inner ear. It has been emphasized that biochemical changes to perilymph and endolymph are likely to result from the impact of the substances penetrating from the middle ear through the round window.

A significant improvement of bone conduction was observed in patients from the group with dry perforation (group 1), without other lesions in the region of the middle ear. The scope of treatment applied to this group resulted in restoring most physiological relationships between the mechanics of the middle ear and the function of the inner ear.

In the patients with permanent discharge from the ear in the preoperative period (group 3), the appropriate pharmacological treatment that preceded the reconstruction of the tympanic membrane and resulted in obtaining the “dry ear” brought about the same postoperative results in terms of bone conduction improvement as in group 1.

It has also been reported that the lesions in the region of the round window have an adverse effect on bone conduction [7,16]. An analysis of patients operated on at the Otolaryngology Teaching Hospital of Jagiellonian University's Collegium Medicum confirms that observation. In the group of patients with the occurrence of adhesions in the tympanic cavity, statistically significant improvement of bone conduction after otosurgery was not observed. The reason for the above observation may be a tendency to restrict the mobility of the ossicular chain as a consequence of even partial recurrence of adhesions after surgery. The highest risk of decreasing the value of bone conduction is observed in the case of adhesions in the niche of the round window.

The elimination of granulation lesions was a positive factor for the future improvement of inner ear function. In such cases the surgery eliminated mucous abnormalities and the toxic effect of mediators of inflammation on inner ear function. However, hearing improvement manifesting itself in a change of the ABG

was not observed in this group, since hearing improvement assessed by postoperative tests was statistically insignificant.

In analyzing factors that affect hearing improvement in patients who underwent myringoplasty, significantly better results were not observed only in the cases where granulation tissue was present in the tympanic cavity and the ossicular chain was not damaged. In the remaining groups *without ossiculoplasty* (without discharge, with discharge, and with adhesions), the observed hearing improvement (manifesting itself in ABG closure) was statistically significant. The observations above are coincident with reports encountered in reference literature from across the world [14,17].

## Conclusions

1. The presence of granuloma-related lesions in the middle ear spaces is likely to impede the improvement of both air conduction and bone conduction.
2. Damage to the ossicular chain rules out the possibility of bone conduction improvement after surgery.
3. The prognosis on tube-related simple chronic otitis media after myringoplasty, with the preserved continuity of the ossicular chain, consists of ABG closure and leads to significant improvement in bone conduction.

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