FUNCTIONAL HEARING RESULTS IN PATIENTS WITH OTOSCLEROSIS BEFORE AND AFTER STAPEDOTOMY
FUNKCIONALNI REZULTATI SLUHA KOD PACIJENATA SA OTOSKLEROZOM PRE I POSLE STAPEDOTOMIJE

Dragan Dankuc, Nemanja Pejaković, Zoran Komazec and Ljiljana Vlaški

Summary – Surgical treatment of otosclerosis with stapedotomy leads to the improvement of subjective and objective problems in patients with otosclerosis. A prospective study included patients who had been treated surgically at the Department for Ear, Nose and Throat in Novi Sad in the period from September 2006 to September 2007. On the basis of the appropriate diagnostic procedures, 33 patients were diagnosed with otosclerosis. Functional hearing was assessed before and after surgery by means of pure tone audiometry. The comparison of functional results before and after surgery revealed no changes in pure tone average of bone conduction threshold (average hearing threshold for hearing range), whereas pure tone average of air conduction and pure tone average of the gap showed statistically significant improvement. The results of this study demonstrated the applicability of stapedotomy as a method for successful management of otosclerosis. This way of examination offers a new perspective on patients’ health, which should be defined as a physical, psychosocial and social well-being, and not only the absence of a disease itself.

Key words: Hearing; Otosclerosis; Stapes Surgery; Audiometry, Pure-Tone

Introduction

Otosclerosis is defined as a continuous process of alteration in bone metabolism of otic capsule in the form of bone resorption and redeposition. It is a disease that affects the bone labyrinth capsule, and is characterized by formation of centers of newly constructed bone, which are usually formed in the area of the oval window and annular ligament, leading to stapes fixation [1]. Otosclerosis is characterized by destruction of the existing and formation of new, initially spongious, and then compact bone. The overall incidence of the disease reveals the variability in distribution according to race, gender, geographic location, familial incidence, pregnancy and age. The disease occurs more frequently in the Caucasian race (white race) than in other races [1-3]. Numerous reports have indicated that otosclerosis is twice as common in women than in men, which refers only to the clinical form of disease [2,4,5]; however, when it comes to the histological form of disease, the ratio between women and men is 1:1 [2]. Otosclerosis process usually affects young adults, and people between 15 and 45 years of age [4]. The most common and, therefore, the most appropriate sub-division of otosclerosis is into the clinically and non-clinically manifested disease. Stapediovestibular form is by far the most common form of the disease.

Current research suggests that heredity, genetic malformations, viral infection, trauma, endocrine disorders, and autoimmune diseases play a role in the etiology of otosclerosis, but none of the hypotheses is accepted as a unique etiopathogenetic theory [6]. Most authors agree that this disease is transmitted by autosomal dominant inheritance with varying degrees of penetration of the gene responsible for the development of histological form of the disease [4,7,8]. Recent studies indicate the existence of nine different chromosomes containing genes responsible for the development of otosclerosis [9].

The definitive diagnosis of otosclerosis is always made by surgical exploration, which confirms the immobility of the stapes and then it is verified histopathologically. Clinical symptoms of otosclerosis include progressive hearing loss and tinnitus. In rare cases, dizziness may occur as well. Depending on the extent of the process, conductive hearing loss can range from 30 dB to 50 dB. In some cases a “mixed” type hearing loss may be apparent, suggesting the labyrinthine otosclerosis.

Histopathological and pathoanatomical studies of otosclerosis are followed by the research oriented towards the treatment modalities and improvement of quality of life of patients suffering from this disease.

By applying different techniques of tympanoplasty and by reconstructing the ossicular chain in chronic otitis media with otosclerotic and timpanosclerotic foci, the pathological process is removed, which results in improved conductive hearing loss [10].

By applying different techniques of tympanoplasty and reconstruction of ossicular chain in chronic otitis media, otosclerotic and timpanosclerotic foci are removed from the middle ear along with the pathological process, providing improvement of conductive hearing loss [10].

Modern indications in the treatment of otosclerosis imply the application of cochlear implants. The cochlear implant has been used at our Department of Ear, Nose and Throat (ENT Department) since
A prospective study of functional hearing results was performed before and after surgical treatment of otosclerosis using stapedotomy method at the ENT Department of the Clinical Center of Vojvodina, Faculty of Medicine Novi Sad.

The study included patients who were surgically treated at the ENT Department in Novi Sad in the period from September 2006 to September 2007. All patients were surgically treated by the same surgeon, using the same operative technique - stapedotomy. During that period, 33 patients underwent surgical treatment, i.e. 22 females and 11 males, aged 23 to 70 years, their average age being 47.2 years. The diagnostic algorithm included the following analysis procedures: anamnesis, clinical examination, tonal audiometry, tympanometry, stapedial reflex testing, Gelle’s test, Bing’s test and calculating of Sullivan’s index. All functional diagnostic procedures were conducted at the Audiology and Vestibulology Ward of the ENT Department in Novi Sad applying the tonal Audiometer - MADSEN ELECTRONICS - OB 822 and tympanometry - Impedance audiometer AT 235.

Tonal audiometry results obtained before and after surgery were compared by the Wilcoxon Signed Rank Test. Bone conduction, air conduction and air-bone threshold at 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz were compared. Subsequently, we compared the average hearing threshold at hearing frequencies (PTA-pure tone average), bone conduction, air conduction and air-bone threshold before and after surgery. PTA was done for all four voice frequencies by adding the values expressed in dB at aforementioned frequencies. The values were then divided by four to obtain the value that can be used in further calculations as the relevant one.

**Results**

The obtained results are given in tables and refer to the scores before and after surgery. The difference in bone conduction at 0.5 kHz before and after surgery was not statistically significant, P = 0.551 (before X = 23.48; after X = 24.09). The difference in bone conduction at 1 kHz before and after surgery was not statistically significant, P = 0.680 (before X = 23.79; after X = 24.24). The difference in bone conduction at 2kHz before and after surgery was statistically significant, P = 0.017 (before X = 35.76; after X = 31.97). Bone conduction remained at the same level as that before surgery in 11 (33%) patients. Better hearing at the aforementioned frequencies was achieved in 15 (46%) patients, whereas hearing loss was recorded in 7 (21%) patients. The difference between bone conduction at 4 kHz before and after surgery was not statistically significant, P = 0.272 (before X = 37.73; after X = 40.15) (Table 1).

**Table 1.** The average bone conduction of the operated ears before and after surgery

<table>
<thead>
<tr>
<th>Bone conduction/ Köštane provodljivosti</th>
<th>Pre operacije</th>
<th>Post operacije</th>
</tr>
</thead>
<tbody>
<tr>
<td>500 Hz</td>
<td>23.48 dB</td>
<td>23.79 dB</td>
</tr>
<tr>
<td>1000 Hz</td>
<td>35.76 dB</td>
<td>37.73 dB</td>
</tr>
<tr>
<td>2000 Hz</td>
<td>31.97 dB</td>
<td>40.15 dB</td>
</tr>
<tr>
<td>4000 Hz</td>
<td>24.09 dB</td>
<td>31.97 dB</td>
</tr>
</tbody>
</table>

The differences in air conduction at 0.5 kHz before and after surgery were highly statistically significant, P = 0.000 (before X = 62.73; after X = 36.52). The difference in air conductivity at 1 kHz before and after surgery was statistically significant, P = 0.000 (before X = 57.42; after X = 31.52). The difference in air conduction at 2kHz before and after surgery was highly statistically significant, P = 0.000 (before X = 51.67; after X = 34.55). The difference in air conduction at 4kHz before and after surgery was statistically significant P = 0.016 (before X = 52.73; after X = 46.06) (Table 2).

The difference between the air-bone gap at 0.5 kHz before and after surgery was statistically significant, P = 0.000 (before X = 39.24; after X = 12.73). As regards the differences of air-bone gap at 500 Hz, an
Improvement by 20 - 30 dB was observed in all 33 patients (100%). The difference between the air-bone gap at 1 kHz before and after surgery was statistically significant, P = 0.000 (before X = 33.64, after X = 8.18). The difference between the air-bone gap at 2 kHz before and after surgery was statistically significant, P = 0.000 (X = before 15.91; after X = 2.58). The difference between the air-bone gap at 4 kHz before and after surgery was statistically significant, P = 0.002 (before X = 14.7; after X = 6.52) (Table 3).

Table 3. The average air-bone gap of the operated ears before and after surgery

<table>
<thead>
<tr>
<th>Air-bone gap/Koštano-vazdušni gep</th>
<th>500 Hz</th>
<th>1 000 Hz</th>
<th>2 000 Hz</th>
<th>4 000 Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before surgery/Pre operacije</td>
<td>39.24 dB</td>
<td>33.64 dB</td>
<td>15.91 dB</td>
<td>14.7 dB</td>
</tr>
<tr>
<td>After surgery/Post operacije</td>
<td>12.73 dB</td>
<td>8.18 dB</td>
<td>2.58 dB</td>
<td>6.52 dB</td>
</tr>
</tbody>
</table>

The difference in bone conduction PTA at all four frequencies before and after surgery was not statistically significant, P = 0.779 (before X = 29.77; after X = 30.00). The difference in air conduction PTA at all four frequencies before and after surgery was highly statistically significant, P = 0.000 (before X = 55.68; after X = 37.01). The difference in air-bone gap PTA at all four frequencies before and after surgery was highly statistically significant, P = 0.000 (before X = 27.12; after X = 7.5) (Table 4).

Table 4. The pure tone average of the bone conduction, air conduction and air-bone gap before and after surgery

<table>
<thead>
<tr>
<th>PTA</th>
<th>Bone conduction</th>
<th>Air conduction</th>
<th>Air - bone gap</th>
</tr>
</thead>
<tbody>
<tr>
<td>Koštane provodljivosti</td>
<td>Vazdušna provodljivost</td>
<td>Koštano-vazdušni gep</td>
<td></td>
</tr>
<tr>
<td>Before surgery/Pre operacije</td>
<td>29.77 dB</td>
<td>55.68 dB</td>
<td>27.12 dB</td>
</tr>
<tr>
<td>After surgery/Post operacije</td>
<td>30.00 dB</td>
<td>37.01 dB</td>
<td>7.5 dB</td>
</tr>
</tbody>
</table>

PTA-prosечни prag sluha za područje slušnih frekvencija

**Discussion**

So far, various surgical techniques have been used to treat otosclerosis, but stapedotomy still remains the method of choice. In our study, all patients were surgically treated by small fenestra stapedotomy of the stapes footplate. The main goal of surgical techniques has always been to improve patients’ hearing function and to eliminate the accompanying symptoms of the disease, such as tinnitus and dizziness.

Most studies dealing with the outcomes of surgical treatment of otosclerosis pertain to audiologic testing before and after surgery, presuming that audiological measurements reflect the patient’s subjective experience regarding the treatment outcome.

The average preoperative bone conduction value at 500 Hz was at the level of 23.48 dB. The average postoperative bone-conduction value was 24.09 dB, which is not considered statistically significant. Thus, it has been stated that the surgery does not affect the bone conduction value at 500 Hz.

In addition, the change of average bone conduction value before and after surgery did not achieve a statistical significance at 1000 Hz.

However, the comparison of the average preoperative and postoperative bone conduction values at 2000 Hz revealed a statistically significant difference. The mean values measured before and after surgery were 35.75 dB and 31.97 dB, respectively.

In 2005, Lazaro et al. reported the mean pre- and postoperative bone conduction values at 2000 Hz to be 32.73 dB and 30.78 dB, respectively [13].

A reduction of ossicular chain fluctuations in otosclerosis leads to difficulties in transmission of stimuli to the inner ear, mostly at frequency of 2000 Hz. Thus, the major drop in bone conduction is observed at this frequency.

In our research, the pre- and postoperative bone conduction values at 4000 Hz were not significantly changed.

Quaranta et al reported the changes of average bone conduction value at 1000 Hz, 2000 Hz and 4000 Hz at the level of -0.02 dB in their study conducted in 2005 [14].

The average air conduction at 500 Hz before surgery was 62.73 dB. After surgery, the average air conduction was 36.52 dB. This result is highly statistically significant, indicating that otosclerosis surgery results in the improvement of conductive hearing loss.

At 1000 Hz, the average preoperative air conduction was 57.42 dB, reaching 31.52 dB after surgery. This result is considered highly statistically significant, confirming the successful outcome of the procedure at the frequency of 1000 Hz.

The mean air conduction values at 2000 Hz were 51.67 dB and 34.55 dB before and after surgery, respectively. This improvement is considered highly statistically significant.

The comparison of the mean pre- and postoperative air conduction values at 4000 Hz revealed a statistically significant difference. The mean values obtained before and after surgery were 52.73 dB and 46.06 dB, respectively.

According to the above results, the functional hearing tests and their comparison demonstrate the effectiveness and success of stapedotomy as a valuable method in treating otosclerosis.

Grolman et al. compared the results obtained after stapedotomy depending on the prosthesis diameter. Their results of average values of air conductivity revealed pre-and postoperative average air conductivity...
values at 500 Hz to be about 55 dB and 22 dB, respectively. The recorded preoperative and postoperative values at different frequencies were as following: at 1000 Hz were around 52 dB and 21 dB; at 2000 Hz around 46 dB and 20 dB, and at 4000 Hz around 47 dB and 25 dB [15].

The results reported by Lazaro et al in their study done in 2005 revealed the following: the average preoperative air conduction at 500 was 60.2 dB before surgery and 36.8 dB after surgery. Preoperative and postoperative values at 1000 Hz were 56.6 dB 34.5 dB, respectively. The scores obtained at 2000 Hz were 52.7 dB before surgery and 36 dB after surgery, whereas mean preoperative and postoperative air conduction values at 4000 Hz were 54.3 dB and 45 dB, respectively [13].

The purpose of otosclerosis surgery and the greatest benefit resulting from it are the improvement of air conductivity and closure of the air-bone gap.

Regarding the air-bone gap, one should bear in mind the possibility of reduction or even complete closure of the gap as a result of decreased bone conduction. Of course, in this case, there is a closure of the air-bone gap, which however presents an unfavorable and adverse outcome of otosclerosis surgery, and is considered a postoperative complication.

The mean air-bone gap at 500 Hz before the surgery was 39.24 dB, whereas the value after surgery was 12.73 dB. This difference was highly statistically significant.

The average air-bone gap at 1000 Hz before surgery was 33.64 dB while the postoperative value was 8.18 dB, which is considered highly statistically significant.

By comparing the average air-bone gap at 2000 Hz, before and after surgery, a highly, statistically significant difference was obtained. The values were 15.91 dB and 2.58 dB before and after surgery, respectively.

The average air-bone gap at 4000 Hz before the operation was at the level of 14.7 dB, whereas the value recorded after surgery was 6.52 dB, resulting in a statistically significant difference.

The relation between the average air-bone gap values before and after surgery cannot be considered a reliable indicator of the success of surgical procedure, especially if there is a decrease in bone conduction during the postoperative period. In our research, no significant decrease in bone conduction was observed, thus the average values for air-bone conduction are significant, and can be considered the valid indicators of success of the surgery.

The comparison of bone conduction PTA values at frequencies 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz before and after surgery revealed no statistically significant differences. The improvement in PTA value of air conduction before and after surgery was statistically significant. Air conduction PTA values before and after surgery were 55.68 dB and 37.01 dB, respectively.

The improvement of pre- and postoperative air-bone gap PTA values was also highly statistically significant. The difference between the air-bone gap PTAs before and after surgery was 19.62 dB. Prior to surgery, the PTA air-bone gap was 27.12 dB and after surgery, the value was 7.5 dB.

The results of our study demonstrated the values of the air-bone gap, evaluated via the PTA–air-bone gap at 500, 1000, 2000 and 4000 Hz, to be up to 20 dB in 97%, up to 15 dB in 88%, up to 10 dB in 70%, and up to 5 dB in 42% of patients. The complete gap closure was accomplished in 15% of patients. In one patient, the air-bone gap after surgery was 21.25 dB; however, the overall improvement rate reached 8.75 dB.

In his study of otosclerosis, Sargent reported that in patients who had undergone otosclerosis surgery the closure of air bone gap within a range up to 15 dB was accomplished in almost 100% of cases, up to 10 dB in 90% and, up to 5 dB in 50% of patients. The complete gap closure was accomplished in 30% of patients. The same author, however, explained that the study had included only the patients with conductive hearing loss with a preoperative gap ranging from 15 to 30 dB [5].

The research of Rauka and Halik (2005), who compared the PTA–air-bone gap before and after surgery at three frequencies (500 Hz, 1000 Hz, and 2000 Hz), demonstrated an improvement of postoperative results. The gap of 10 dB or less was observed in 85.19% of patients, whereas the gap level up to 20 dB or less was recorded in 97.04% of patients. In 29.6% of patients, the postoperative PTA gap was higher than 20 dB, which fully corresponds with the results of our study. These patients underwent the small fenestra stapedotomy on the stapes footplate by the use of argon lasers. The same authors reported the improvement of the air-bone gap in 81.48% of cases, reaching 17 dB at 4000 Hz. In our research, the improvement was achieved in 69% of the patients, the score being 8.2 dB [16].

The research of Belgin and Yilmaz, done in 2004, included 68 patients and 83 operated ears. The authors reported the improvement of the air-bone gap of 30.8 dB at 500 Hz, whereas the scores at 1000 Hz and 2000 Hz were 25.5 dB and 14.3 dB, respectively. The increase of 2.9 dB at 4000 Hz was not statistically significant [17].

Our study demonstrated the following improvement of average air-bone gap values: at 500 Hz by 26.5 dB, at 1000 Hz by 25.4 dB, at 2000 Hz by 13.3 dB, and at 4000 Hz by 8.2 dB.

When the same results are interpreted from the aspect of average air-bone gap reduction from 39.24 dB to 12.73 dB at 500 Hz, a statistically significant improvement is observed. Examining the same results in a view of average air-bone gap reduction from 39.24 dB to 12.73 dB at 500 Hz strongly suggests a statistically significant improvement. The obvious reduction of average values of air-bone gap at 1000 Hz, which decreased from 33.64 dB to 8.18 dB, was also highly statistically significant. At the level of 2000 Hz, the average preoperative air-bone gap was 15.91 dB, whilst its value after surgery was 2.58 dB. This result was also highly statistically significant. Contrary to the aforementioned studies, our results at 4000 Hz showed a statistical significance, and the value of the average air-bone gap was reduced from 14.7 dB to 6.52 dB.
Conclusion

Stapedotomy is the method of choice for the surgical treatment of otosclerosis since the comparison of pre- and postoperative results revealed the significant and statistically verified improvement of air conduction at 0.5, 1, 2 and 4 kHz, as well as the reduction of air-bone gap, while maintaining bone conduction.

The improvement of bone conduction after stapedotomy was confirmed only at 2 kHz and in some patients, which can be explained by the phenomenon of Carhart’s notch, which is characteristic of otosclerosis.

The comparison of functional results before and after surgery revealed that the average hearing threshold for the frequency range for bone conduction remained unchanged, while the average hearing thresholds for the frequency range by air conduction and air-bone gap were significantly improved.

Furthermore, the situation regarding the symptoms as well as the social and emotional aspect of life quality was much better after surgery. This research method provides a complete insight into the health status of the patient, which should be defined as the state of physical, mental and social well-being and not simply the absence of disease itself.

This study has confirmed the success of stapedotomy as a method of surgical treatment of otosclerosis.

References