Sensorineural Hearing Loss in Otosclerosis Surgery

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ABSTRACT

Background: During otosclerosis surgery, operative trauma can lead to decreased bone conduction.

Aims: The study aims to observe the bone conduction changes after otosclerosis operations and analyse possible factors affecting the postoperative decrease in bone conduction.

Material and Methods: Authors retrospectively processed the data of 109 patients and evaluated pure tone audiometry before surgery and consequently 2 days, 1 month and 1 year after surgery.

Results: We noted a deterioration of bone conduction >5 dB on the second postoperative day in 28% (30/109) of patients, which persisted one year after the surgery in 9% (10/109) cases. Analysis of individual factors affecting bone conduction loss revealed a higher risk of permanent loss of bone conduction in patients with early postoperative loss in higher frequencies, in older patients and patients with a preoperative threshold of bone conduction >20 dB. Revision surgery was not a statistically significant factor.

Conclusion and Significance: The bone conduction decrease after otosclerosis surgery is usually temporary. The recovery of bone conduction is influenced by the age of patients and the level of bone conduction before the surgery. The early postoperative decrease of bone conduction in higher frequencies is a negative predictive factor for permanent hearing loss.

KEYWORDS

otosclerosis; surgical trauma; sensorineural hearing loss

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INTRODUCTION

Otosclerosis is a disease of the inner ear bony labyrinth. The most frequent symptoms are hearing loss, conductive or mixed, and tinnitus (1). The cause of conductive hearing loss is the fixation of the stapes to the oval window. The cause of the sensorineural hearing loss is not fully explained (2–4).

The causal treatment of otosclerosis is currently unknown. Thus, the surgical effort focuses on the disease's main symptom, conductive hearing loss. The surgery is considered if the air-bone gap is greater than 20 dB (5). The replacement of stapes with prostheses is the basic principle of the operation. The surgical techniques have improved a lot in the last decades; however, the basic principle of the operation has not changed since the 1950s.

This article aims to analyse the audiological outcomes of otosclerosis surgery for 1 year, to monitor the change of bone conduction in pure tone audiometry after the surgery and to find predictive factors indicating permanent hearing loss due to surgical trauma.

MATERIAL AND METHODS

The retrospective study evaluated data from patients diagnosed with otosclerosis who were operated on at the Department of Otorhinolaryngology and Head and Neck Surgery in the period 2013–2017.

In the case of primary operation, the predominant method was stapedotomy with piston (titanium) insertion, which was performed in 88 (81%) patients. The complete stapedectomy with removing the entire stapedial footplate was performed in only 1 (1%) case.

During the revision operations, a manubrio-vestibulopexy was performed in 3 (3%) patients. In 6 (6%) patients, the adhesions were disrupted, and the original prosthesis was left; in 11 (10%) patients, the original prosthesis was replaced with a new one.

In our workplace, we use cold instruments as standard for platinotomy – a perforator and hooks on the stapes footplate. Neither a power drill nor a laser were used for platinotomy. We follow the rule of not suctioning directly from the hole of the oval window after perforation of the footplate. In our group, it was impossible to retrospectively determine the suction data and use it for statistical analysis due to the insufficient description of this procedure in the operative protocol.

The pure tone audiograms were recorded for each patient before surgery, 2 days (only bone conduction), 1 month, and 1 year after surgery. For the statistical analysis, we evaluated four crucial frequencies (0.5, 1, 2, 4 kHz) of bone conduction before surgery, 2 days, 1 month and 1 year after surgery, air conduction before surgery, 1 month and 1 year after surgery. Possible predictive factors leading to permanent hearing damage due to surgical trauma were analysed (6, 7). These were:

1. Age – younger than 40 years and aged 40 and older
2. Gender – men and women
3. Type of surgery – first surgery and revision surgery
4. Preoperative sensorineural component of hearing loss – £20 dB and >20 dB
5. Side of the surgery – left and right ear

We considered an impairment of >5 dB as a significant bone conduction impairment. The following tests were used for statistical processing: the Kolmogorov-Smirnov, Spearman and Fisher exact tests.

RESULTS

In the study period, 143 patients were operated for otosclerosis. After excluding patients with incomplete documentation, 109 patients were analysed: 78 (72%) women and 31 (28%) men. Primary surgery was performed in 89 (82%) cases and revision in 20 (18%) cases. The right ear was operated in 51 (47%) cases and the left ear in 58 (53%) cases. The average age was 47 (±11) years. There were 84 (77%) patients aged 40 years and older and 25 (23%) younger than 40 years.

Before the surgery, the average hearing loss at the observed frequencies was 56 (±15) dB, and the bone-air gap was 30 (±9) dB.

One month after the surgery, hearing improved by an average of 19 (±18) dB, hearing improved in 101 (93%) patients, and a significant improvement of >10 dB occurred in 82 (75%) patients (Figure 1). The average bone-air gap was 12 (±8) dB, bone-air gap £ 10 dB was in 59 (54%) patients.

One year after the surgery, the average hearing improvement was 23 dB (±16), hearing improved in 102 (94%) patients, and significant improvement >10 dB in 91 (84%) patients. The average bone-air gap was 10 (±8) dB, bone-air gap £10 dB was in 69 (63%) patients.

During revision surgeries, hearing improved in all 20 (100%) patients 1 month after surgery. The average bone conduction value of the patients before surgery was 26 (±16) dB. On the second postoperative day, the average bone conduction value was 29 (±12) dB. Worsening occurred in 30 (28%) patients. The difference was statistically significant (p = 0.020). One year after surgery, the average value of bone conduction was 23 (±11) dB; compared to the preoperative state, deterioration was noted in 10 (9%) patients, but the decrease was not statistically significant (p = 0.12) (Figure 2). There were no major postoperative complications, and deafening of the operated ear did not occur in any patient.

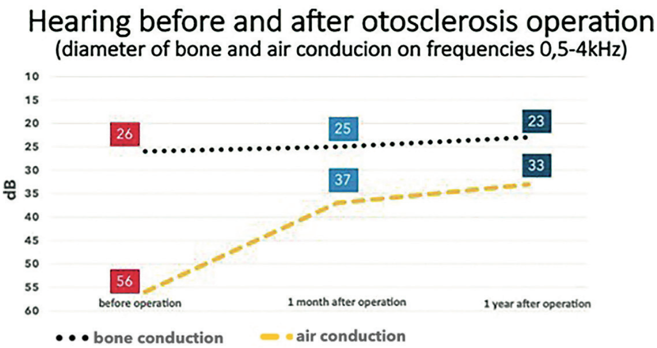

Fig. 1 Hearing before and after stapes surgery (diameter of bone and air conduction on frequencies 0,5–4 kHz).

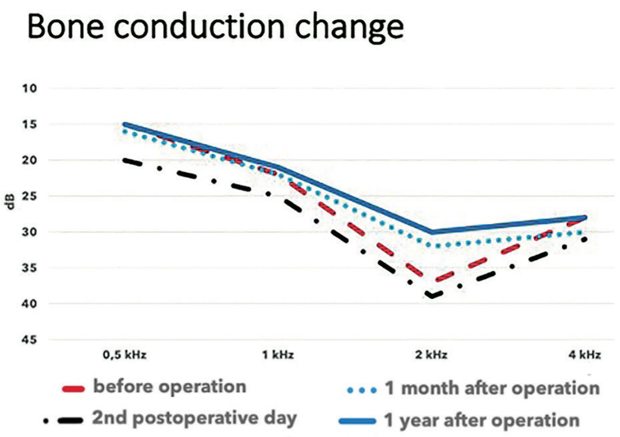

Fig. 2 Bone conduction – before surgery, second postoperative day, 1 month and 1 year after surgery.

frequency	2nd postoperative day age < 40 (n = 25)	1 year after operation age < 40 (n = 25)	2nd postoperative day age ≥ 40 (n = 84)	1 year after operation age ≥ 40 (n = 84)
0,5 kHz	5 (20%)	2 (8%)	25 (30%)	7 (8%)
1 kHz	4 (16%)	2 (8%)	21 (25%)	9 (11%)
2 kHz	6 (24%)	3 (12%)	20 (24%)	6 (7%)
4 kHz	4 (16%)	3 (12%)	21 (25%)	***17 (20%)*** ***p = 0,01***

Tab. 1 Number of patients with a decrease in bone conduction (≥10 dB) in relation to age.

When analysing the average bone conduction changes at individual frequencies on the second postoperative day, the decreases were greater in lower frequencies. One year after surgery, bone conduction improved at a frequency of 2 kHz compared to the preoperative audiogram. At other frequencies, the average value of bone conduction corresponded to the preoperative status (Figure 2). Patients who had early postoperative bone conduction loss ≥ 10 dB at frequencies of 2 and 4 kHz remained significantly impaired bone conduction one year after surgery (p<0.025).

EFFECT OF AGE ON POSTOPERATIVE DECREASE IN BONE CONDUCTION

We compared the postoperative decrease in bone conduction in patients aged 40 years and older (84 patients – 77%) and patients younger than 40 years (25 patients – 23%). In elderly patients, the preoperative mean bone conduction value was 27 (±11) dB. On the second postoperative day, the average bone conduction value was 31 (±11) dB; deterioration occurred in 25 out of 84 (30%) operated patients, and the decrease was statistically significant (p = 0.048).

One year after surgery, the average value of bone conduction was 25 (±12) dB. We noted a deterioration compared to the preoperative condition in only 8 (10%) patients; the decrease was not statistically significant (p>0.1).

In patients younger than 40, the preoperative mean value of bone conduction was 19 (±5) dB. On the second postoperative day, the average bone conduction value was 23 (±12) dB, and deterioration occurred in 4 out of 25 (16%) patients. The difference was not statistically significant (p = 0.073). One year after surgery, the average value of bone conduction was 18 (±8) dB. We noted a deterioration compared to the preoperative condition in only 2 (8%) patients; the decrease was not statistically significant (p>0.1). When analysing individual frequencies, on the second postoperative day, there was a statistically significant decrease in bone conduction in patients aged 40 and older at all frequencies compared to patients younger than 40 (p<0.025). One year after surgery, we noted a significant difference between the groups of younger and older patients only at a frequency of 4 kHz (p = 0.010) (Table 1).

THE INFLUENCE OF THE PREOPERATIVE SENSORINEURAL COMPONENT OF HEARING LOSS ON THE POSTOPERATIVE DECREASE IN BONE CONDUCTION

Preoperatively, 43 (39%) patients had a normal mean bone conduction value (£20 dB). In this group, deterioration of bone conduction occurred on the second postoperative day in 15 (35%) patients, and deterioration persisted in 3 (7%) patients one year after surgery (p = 0.25). In the group of 66 (61%) patients with a preoperatively bone conduction threshold >20 dB, deterioration of bone conduction occurred on the second postoperative day in 15 (23%) patients. The deterioration persisted in 7 (11%) patients a year after surgery. When analysing individual frequencies, we demonstrated a statistically significantly greater decrease in bone conduction at 1 and 4 kHz on the second postoperative day and one year after surgery in patients with a preoperative sensorineural component of hearing loss >20 dB

frequency	2nd postoperative day BC ≤ 20 dB (n = 43)	1 year after operation BC ≤ 20 dB (n = 43)	2nd postoperative day BC > 20 dB (n = 66)	1 year after operation BC > 20 dB (n = 66)
0,5 kHz	15 dB	10 dB	24 dB	18 dB
1 kHz	18 dB	14 dB	30 dB	***25 dB*** ***p = 0,001***
2 kHz	32 dB	22 dB	44 dB	35 dB
4 kHz	21 dB	16 dB	38 dB	***36*** dB ***p = 0,001***

Tab. 2 Number of patients with a decrease in bone conduction (≥10 dB) in relation to preoperative bone conduction threshold.

(p<0.001), the differences were not significant at the 2 kHz frequency (p>0.1), at the deep frequency of 0.5 kHz, on the other hand, there was a significantly greater decrease in patients with preoperatively normal bone conduction (p<0.001) (Table 2).

IMPACT OF REVISION OPERATION

During revision operations, the sensorineural component worsened in 4 (20%) out of 20 patients; bone conduction was adjusted to the preoperative level in all patients within a year of the operation. Compared with primary operations, no statistically significant difference in bone conduction decrease was noted (p>0.1).

DISCUSSION

Sensorineural hearing loss in patients with otosclerosis develops as part of the disease itself. So far, it has not been clarified precisely how the auditory epithelium of the inner ear is affected. Current studies show a relationship between the inflammatory involvement of the inner ear by the measles virus and cytokines released from otosclerotic foci (8). During the histological examination of an otosclerotic deposit, we can find different cellular activity, according to which otosclerotic deposits are divided into four stages. The cellularity of the deposit, the presence of osteoclasts and osteoblasts, vascularisation and the amount of intercellular collagen matrix are evaluated. Stage I indicates the most active deposits, and stage IV is completely inactive deposits (8). In the early stages, cytokines TNF-α, interleukin-1, interleukin-6, parts of the complement C3a, C3b, and C5a are released from the otosclerotic deposit. These molecules penetrate the perilymph and can affect the function of the hair cells of the inner ear (9–11). The greatest attention is paid to the cytokine TNF-α, which increases the activity of osteoclasts and, thus, pathological bone remodelling (2, 3).

The development of radiodiagnostic techniques enables targeted imaging of the area of otosclerotic deposits. Shin et al. demonstrate on HRCT a relationship between the extent of the otosclerotic deposit of the otic capsule and the degree of sensorineural hearing loss. In patients with HRCT, evidence of an otosclerotic deposit spreading into the endosteum showed a significant decrease in bone conduction (12).

In patients undergoing surgery for otosclerosis, there is a new factor contributing to the deterioration of the sensorineural component of hearing loss – surgical trauma. This risk leads operators to introduce new modifications of the original operation – stapedectomy. Today, it is already standard practice to switch to operations preserving a larger part of the stapes plate with an effort to create an opening corresponding to the size of the stapes prosthesis. This significantly reduces perilymph leakage during surgery and in the early postoperative period and reduces the risk of worsening sensorineural hearing loss (13–15).

In our group of patients, the stapedotomy technique completely prevailed. Removal of the entire footplate (stapedectomy) was performed in only one patient.

The risk of postoperative hearing loss is not the same at all hearing frequencies. Several works deal with the frequency-specific analysis of postoperative deterioration of bone conduction (16, 17). Losses are more often noted in higher frequencies. Strömbäck et al. reported deterioration of bone conduction at frequencies 4–8 kHz >10 dB in 6.5% of patients (17).

In our group of patients, the early decrease in bone conduction was greater in lower frequencies, but the early decrease in high frequencies is more prognostically significant. In patients who experienced a decrease in bone conduction at frequencies of 2 and 4 kHz on the second postoperative day, significantly worse bone conduction persisted even one year after surgery. We observed an overall postoperative improvement in bone conduction at a frequency of 2 kHz. It could be explained by a Carhart notch theory (24). Carhart attributed the phenomenon of a reduction in bone conduction sensitivity with the peak in 2 kHz to "mechanical factors associated with stapedial fixation." The Carhart notch is not an accurate indication of "cochlear reserve", and this apparent bone conduction loss may be corrected by surgical intervention (25, 26).

One of the possible risk factors for postoperative decrease in bone conduction is pre-existing sensorineural hearing loss. Currently, this risk factor is not clearly accepted. Most studies demonstrate a higher risk of postoperative hearing impairment in patients with preoperative sensorineural hearing loss (16–20); however, studies refuting this have also been published (16). In our set, the results were also ambiguous, the decrease varied at individual frequencies. We noted a more significant decrease in preoperative sensorineural hearing loss at frequencies of 1 and 4 kHz; at a frequency of 2 kHz, the difference was not significant, and at a deep frequency of 0.5 kHz, on the contrary, the decrease was lower compared to the normal preoperative bone conduction threshold.

The risk of traumatising the structures of the inner ear comes at the stage of handling the stapes plate. Yin et al. did not demonstrate acoustic trauma in cadavers when milling the footplate with a diamond bur but did demonstrate the risk of acoustic trauma from suction noise in the oval window fossa (20).

Attention is also paid to the age of the patients. Bauchet et al. in their analysis, demonstrated a higher sensitivity to early (4–6 weeks after surgery) postoperative deterioration of bone conduction in patients older than 40 years (16). However, when checked 9 months after the operation, the difference against younger patients was no longer statistically significant, and the authors do not consider age to be a risk factor for permanent hearing impairment due to surgical trauma. In our group of patients, the early decrease in bone conduction was significantly greater in older patients at all frequencies, one year after surgery only at the frequency of 4 kHz ($p = 0.010$). A frequently discussed issue is revision operations. Otosclerosis reoperations are considered risky for inner ear damage, the results of revision operations are uncertain (21–23). In our file, the revision operations that were performed were successful. One month after the operation, all patients experienced improved hearing. One year post-operation, 95% of patients showed an average improvement of more than 10 dB. The results also demonstrated that, compared to primary operations, our group did not exhibit a higher risk of bone conduction decline.

LIMITATIONS

This study has several limitations. First, it is a retrospective study, which inherently carries risks of bias and incomplete data. Additionally, incomplete documentation posed challenges in analysing all relevant variables. Some patients missed their scheduled follow-up appointments, while others attended follow-ups at different healthcare facilities, making it difficult to track their outcomes. Finally, certain medical records were unavailable or could not be retrieved, further limiting the completeness of the data.

CONCLUSION

Stapes surgeries improve air conduction in more than 90% of patients. However, surgical trauma could decrease bone conduction. In most patients, the decrease of bone conduction after surgery is only temporary. There is a higher risk of permanent sensorineural loss in patients with a postoperative decrease in bone conduction in higher frequencies (2 and 4 kHz) 2 days after the surgery, in patients aged 40 years and more (for frequency 4 kHz) and in patients with a pre-existing sensorineural component of hearing loss (for frequencies 1 and 4 kHz).

ETHICAL APPROVAL

The study was conducted retrospectively using fully anonymised data, which means that no personal or identifiable information about patients was accessed or used. As a result, the study did not involve any interventions or direct contact with patients, and there was no risk to their privacy or well-being. For these reasons, approval from the ethics committee was not required.

DISCLOSURE STATEMENT

No potential conflict of interest was reported by the author(s).

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