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Frequency-Specific Analysis of Hearing Outcomes after Surgery for Chronic Ear Diseases

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Frequency-Specific Analysis of Hearing Outcomes after Surgery for Chronic Ear Diseases

Abstract

Objective. To examine the relationship between different surgical factors and frequency-specific hearing results following surgery for chronic ear disorders.

Methods. We reviewed retrospectively data of 246 patients with chronic ear diseases who had surgery between Jan 2019 to Dec 2020. Seventy-three patients did not fulfil the criteria and were excluded. Air conduction threshold(AC), bone conduction threshold(BC), and air-bone gap(ABG) were tested at 250-4000Hz, respectively. Frequency-specific results were investigate in relation to various surgical factors.

Results. The radical mastoidectomy group and tympanoplasty group significantly improved in AC changes at every frequency. In the tympanoplasty group, ABG at all frequencies except 4,000 significantly improved. AC improved at low and mid frequencies when ossicular reconstruction was conducted. In all groups, BC data revealed significant improvements at 500, 1000 and 2000Hz.

Conclusions. The hearing improved significantly postoperatively in AC and ABG test, mainly at low and mid frequencies. The BC improved significantly at 500-2000Hz.

Keywords Frequency; Conductive hearing loss; Surgery; Chronic ear diseases

Introduction

The main purposes of chronic otitis media (COM) surgery are to re-establish the protective barrier of the middle ear and improve hearing [1]. However, as variations in surgical method, lesion severity, and other factors can alter the comparability of surgical results, the study results that have been reported do not show good agreement [2]. Pure tone audiometry is routinely used to assess pre-and postoperative hearing. Most clinical research, on the other hand, have only assessed average pure tone threshold, rather than frequency-specific hearing results. Frequency-specific hearing studies are important since the same average pure tone threshold does not always lead to the same patterns of hearing perception [3]. Therefore, we conducted a retrospective study in which we assessed frequency-specific hearing results based on potential influencing factors to give evidence for frequency-specific postoperative hearing rehabilitation.

Materials and methods

We reviewed retrospectively data of consecutive 246 patients with COM who had surgery at our hospital between Jan 2019 to Dec 2020. 173 patients with pre-and postoperative pure tone audiometry data were included in the analysis. Patients with adhesive otitis media, revision surgery, and failure surgical procedures were excluded. The surgical procedures were performed by one otology surgeon. The selection of surgical approach is determined by the range of lesion as well as the preoperative status of hearing and facial nerve function. Canal wall-down tympanoplasty refers to canal wall mastoidectomy plus tympanoplasty.

Pure tone audiometry was conducted in a double-chamber anechoic room using standard procedures. All patients had pre-operative pure tone audiometry within one week of surgery. Air conduction threshold (AC), bone conduction threshold (BC), and air-bone gap (ABG) were tested at 250, 500, 1000, 2000, and 4000 Hz, respectively. Post-operative pure tone audiometry was examined using the same techniques one year after surgery. At these frequencies, changes in AC, BC, and ABG were calculated between pre- and postoperative examinations. Statistical analysis was performed for each frequency by comparing pre-and postoperative mean values. A positive value indicates improvement and a negative value indicates deterioration.

According to the different surgical procedures, patients were divided into two subgroups: tympanoplasty vs. canal wall-down tympanoplasty; which were also divided into two subgroups according to the type of ossicular replacement: partial ossicular replacement prosthesis (PORP) vs. total ossicular replacement prosthesis

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(TORP) vs. none (Table 1).

Table 1 Distribution of cases in different groups.

Statistical analyses were performed using SPSS 21.0 software. The metering data were expressed as mean ± SD and the significance analysis using t-test. The categorical variables were compared using the Chi-square test or Fisher's exact test. $P < .05$ indicates that the difference is statistically significant.

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Results

Among the 173 COM patients (173 ears), ages ranged from 10 to 74 years (median, 45 years). There were 66 males and 107 females, with a male/female ratio of 1:1.62, of which 91 (52.6 %) were left ears. Of the total cohort, hearing in all frequencies improved significantly postoperatively in AC (Fig 1a) and ABG (Fig 1c) test. BC (Fig 1b) significantly improved at 500, 1000 and 2000 Hz.

Fig 1 Preoperative and Postoperative frequency-specific hearing results in AC, BC, and ABG. a, Preoperative and postoperative levels in AC. B, Preoperative and postoperative levels in BC. C, Preoperative and postoperative levels in ABG.

Hearing results and surgical method

The canal wall-down tympanoplasty group and tympanoplasty group significantly improved in AC changes at every frequency. ABG results in the tympanoplasty group showed improvement at every frequency. In the canal wall-down tympanoplasty group, ABG at all frequencies except 4,000 (P =.069) significantly improved. BC changes in the canal wall-down tympanoplasty group and tympanoplasty group were significantly improved at 500, 1000, 2000 Hz (Fig 2).

Fig 2 Analysis by surgical methods (tympanoplasty vs. canal wall-down tympanoplasty).

Ossicular replacement comparison

In the 'None' group, AC, and BC, results significantly improved at 250, 500, 1000, 2000 Hz. ABG changes were significantly improved at 250, 500, 1000 Hz. Using the TORP replacement, AC and BC indicate significant differences at 250, 500, 1000, 2000

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Hz and 1000, 2000, 4000Hz, respectively. ABG change statistically improved only at 500 and 1000 Hz. In the PORP group, AC and ABG significantly improved at every frequency. BC data revealed significant improvements at 500, 1000 and 2000 Hz (Fig 3).

Fig 3 Analysis of the types of ossicular replacement (None vs. TORP vs. PORP).

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Discussion

This study compared pre-and postoperative frequency-specific hearing outcomes in patients with COM. As anticipated, all frequencies of the group showed significant postoperative improvement in hearing in the AC and ABG tests. The gain is most prominent at low and middle frequencies. This is consistent with previous studies [4]. The normal middle ear pressure gain (a result of ossicular coupling) is frequency-dependent [5]. As noted by Choi HG et al. that the mean gain decreases 6 dB or less per octave for frequencies above 1000 Hz [3]. The low and middle-frequency improvements may represent a normalization of the ossicular coupling effect following reconstructive surgery. In addition to AC elevation, some patients with COM also have BC elevation. An elevation in BC can result from tympanosclerosis, stapes fixation, round window membrane alteration, tympanic membrane perforation, and ossicular chain disruption or fixation [6]. The current study found that, with the exception of 250 and 4000 Hz, BC significantly improved in the whole cohort. The ossicular chain has a large resonance effect at 500-2000 Hz. Weakness or disappearance of resonance caused by the destruction of the ossicular chain can lead to BC change at 500-2000 Hz, and BC can be improved when the continuity and resonance of the ossicular chain are restored through reconstructive surgery [5-7].

At all frequencies except 2000 Hz, the hearing improvement of patients who underwent tympanoplasty was better than that of patients who underwent canal wall-down tympanoplasty in this study. The difference in efficacy between tympanoplasty and canal wall-down tympanoplasty has typically been ascribed to poor Eustachian tube function and greater disease severity in patients requiring canal wall-down tympanoplasty [8]. Furthermore, Quaranta et al. claimed that an intact posterior canal wall was considered a predictor of the better hearing result in ossiculoplasty [9]. Hearing improvement at 2000Hz was significantly better in the canal wall-down tympanoplasty group than in the tympanoplasty group in our investigation. This was consistent with results in research by Şevik Eliçora S et al [4]. It was perhaps relevant that the intact ossicular chain has the greatest impact on hearing at 2000 Hz [10]. The BC changes results were superior in the canal wall-down tympanoplasty group compared with the tympanoplasty group at 250-2000 Hz. The canal wall-down tympanoplasty group had poorer postoperative BC outcomes compared to the tympanoplasty group at 4000 Hz. Excessive ossicular chain movement, vibration or noise from drilling, or other inner ear disruption are all associated with high-frequency sensorineural hearing loss (e.g. strong suction or thermal damage) [11-13]. Generally, canal wall-down tympanoplasty has more drilling time in the middle ear near the stapes and oval window, and the BC seems to be more susceptible to its adverse effect at 4000 Hz.

Surprisingly, the TORP group had the best hearing improvement, followed by the PORP group and the None group at all frequencies except 1000 Hz. None group was closer to normal hearing, to begin with, and had less room for improvement. Most studies assumed that PORP was associated with superior postoperative hearing outcomes when compared with TORP [3]. They suggest that the stapes suprastructure plays an important role in hearing [14], and the stability between TORP and stapes floor is inadequate and prone to displacement, resulting in the interruption of TORP and stapes footplate connection. But in their studies, postoperative audiometry tests were generally conducted about three months after surgery. It is our opinion that the residual stapes in subsequent recovery may continue to be disrupted and adhesion with the surrounding tissue. Furthermore, ossicular coupling of TORP may be superior to that of PORP [15]. Cadaveric temporal bone studies support this viewpoint and considered that TORP placement to a stapes footplate offers acoustic advantages over other ossiculoplasty techniques. The reduced middle ear pressure can be restored after ossichoplasty. Therefore, the results suggest that AC changes occurred principally at lower and mid frequencies, with no substantial changes at higher frequencies. Tonndorf et al. believes that the influence of ossicular chain mechanics on BC is expressed at most as the improvement for the frequency of 2000 Hz, which is caused by the reduction or elimination of resonance within the ossicular chain [16]. Similarly, we discovered that three groups all showed significantly improved at 1000-2000 Hz.

This study is limited by its retrospective nature and small sample size. And other confounding factors, such as infection degree, operator experience and surgery duration, could influence study results. In addition, hearing data at 6000Hz were lacking in this study. Although 6000Hz has little effect on the verbal communication, the relevant changes still need to be further studied.

Summary Statement

- The current most study only assessed average pure tone threshold after middle ear surgery, rather than frequency-specific hearing results
- This audit showed that the hearing improved significantly postoperatively in AC and ABG test, mainly at low and mid frequencies
- Postoperative frequency-specific hearing results affected by variances in surgical method, ossicular replacement
- This study provides a basis for postoperative frequency-specific hearing rehabilitation

Conclusions

In summary, we systematically evaluated the effect of hearing reconstruction at different frequencies after surgery. The hearing improved significantly postoperatively in AC and ABG test, mainly at low and mid frequencies. The BC improved significantly at 500-2000Hz. Postoperative preparation for high-frequency hearing rehabilitation may be needed.

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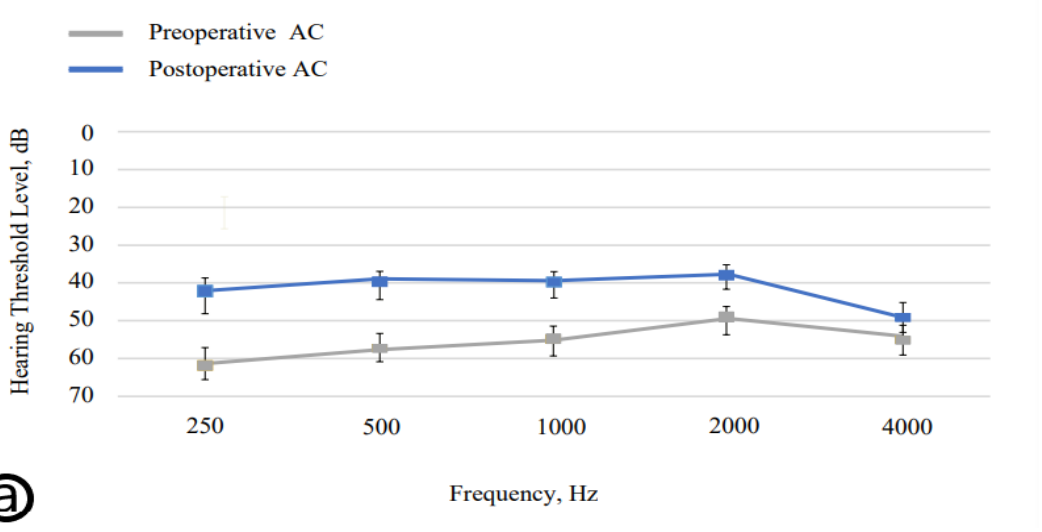
Table 1 Distribution of cases in different groups.

	No. of patients (%)
Surgical method	
Tympanoplasty, n	127(73.4)
Canal wall-down tympanoplasty, n	46(26.6)
Ossicular replacement	
TORP,n	17(9.8)
PORP,n	107(61.8)
None,n	49 (28.3)

TORP total ossicular replacement prosthesis, PORP partial ossicular replacement prosthesis.

Fig 1 Preoperative and Postoperative frequency-specific hearing results in AC, BC, and ABG. a, Preoperative and postoperative levels in AC. B, Preoperative and postoperative levels in BC. C, Preoperative and postoperative levels in ABG.



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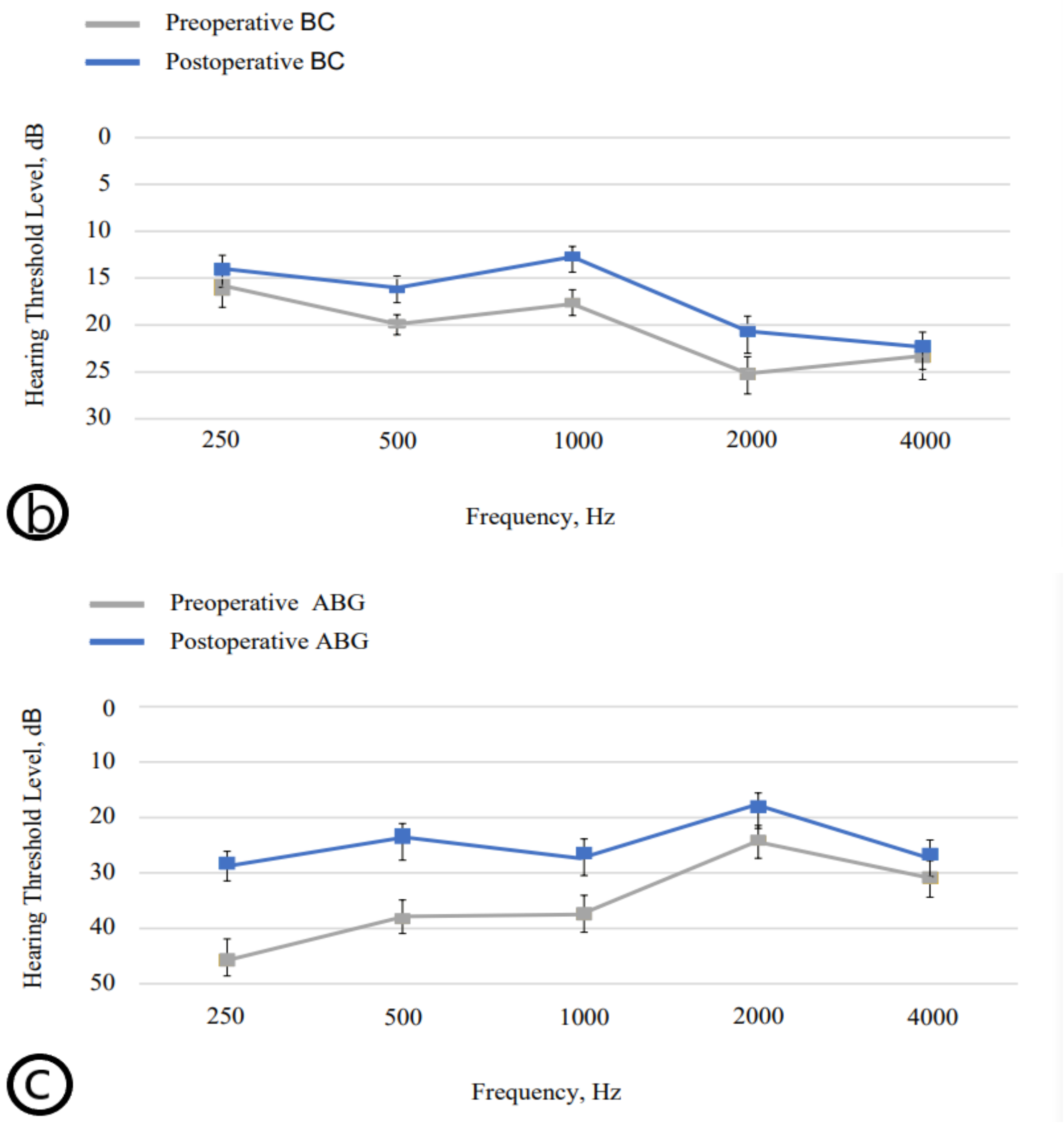

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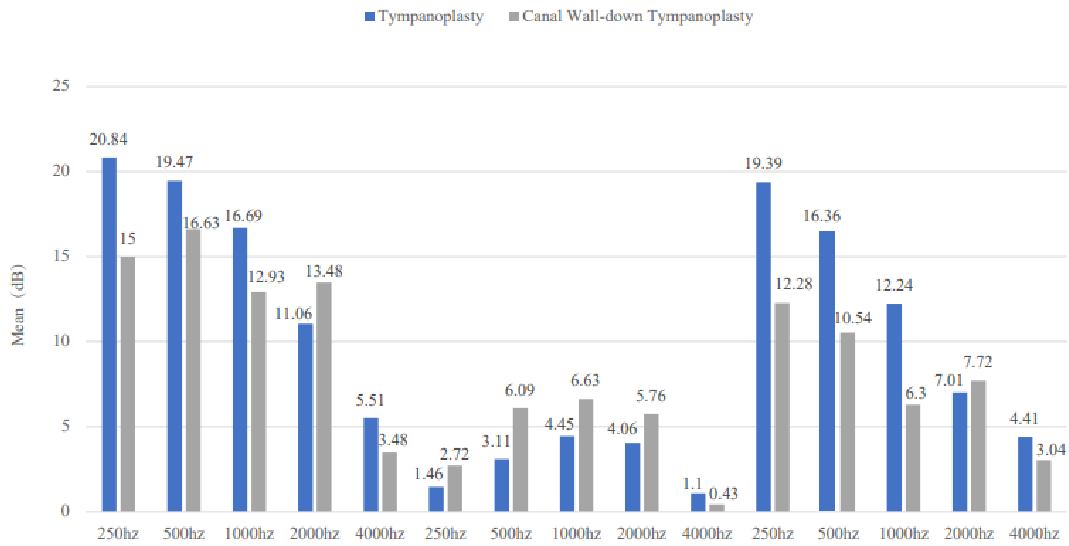
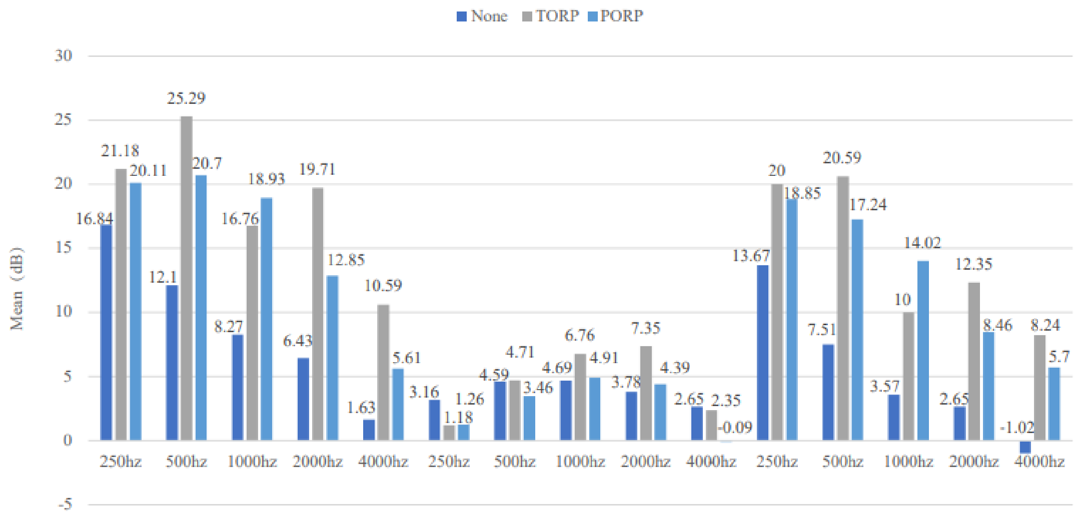


P=0.000	P=0.000	P=0.000	P=0.000	P=0.000	P=0.066	P=0.000	P=0.000	P=0.000	P=0.219	P=0.000	P=0.000	P=0.000	P=0.000	P=0.000
P=0.000	P=0.000	P=0.000	P=0.000	P=0.000	P=0.054	P=0.001	P=0.000	P=0.001	P=0.623	P=0.000	P=0.000	P=0.001	P=0.006	P=0.138

AC changes：preop-postop BC changes：preop-postop ABG changes：preop-postop

P values represent significance of hearing change from preoperative to postoperative follow-up.

Fig 3 Analysis of the types of ossicular replacement (None vs. TORP vs. PORP).



P=0.000	P=0.000	P=0.000	P=0.000	P=0.484	P=0.038	P=0.000	P=0.000	P=0.002	P=0.156	P=0.000	P=0.000	P=0.033	P=0.055	P=0.620
P=0.001	P=0.000	P=0.002	P=0.002	P=0.210	P=0.783	P=0.142	P=0.000	P=0.000	P=0.030	P=0.143	P=0.041	P=0.033	P=0.665	P=0.660
P=0.000	P=0.000	P=0.000	P=0.000	P=0.000	P=0.097	P=0.000	P=0.000	P=0.000	P=0.901	P=0.000	P=0.000	P=0.000	P=0.000	P=0.000

AC changes：preop-postop BC changes：preop-postop ABG changes：preop-postop

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