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

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Abstract

Objective To analyze frequency-specific hearing results surgery for chronic ear diseases, in relation to various surgical factors. Study design Retrospective cohort study. Setting Tertiary referral centre. Participants A total of 173 patients with chronic ear diseases who underwent surgical management at our hospital. Main outcome measures Air conduction threshold (AC), bone conduction threshold (BC), and air-bone gap (ABG) were tested at 250, 500, 1000, 2000, and 4000 Hz, 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 ($P = .069$) significantly improved. AC improved at low and mid frequencies when ossicular reconstruction was conducted. Different tympanic membrane repair materials showed significant improvement in AC at all frequencies. In all groups, BC data revealed significant improvements at 500, 1000 and 2000 Hz. Conclusions The hearing improved significantly postoperatively in AC and ABG test, mainly at low and mid frequencies. The BC improved significantly at 500-2000Hz.

Introduction

The main purposes of chronic otitis media (COM) surgery are to re-establish the protective barrier of the middle ear and improve hearing. However, current study results vary significantly since the comparability of surgical results can be affected by variances in surgical method, repair materials, lesion severity, and so on. 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 [1]. Therefore, we conducted a retrospective study in which we assessed frequency-specific hearing results based on possible 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 underwent surgical management at our hospital between Jan 2019 to Dec 2020. 173 patients with pre-and postoperative pure tone audiometry data were included in the analysis. Exclusion criteria included patients with revision surgery, adhesive otitis media, and unsuccessful surgical. 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. All procedures involving human participants followed the institutional research committee ethical standards in accordance with the 1964 Helsinki declaration and its later amendments. This was retrospective study, thus no informed consent was needed.

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. One year following surgery, the same methods were used to examine post-operative pure tone audiometry. 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.

Based on possible influence factors, these COM patients were retrospectively categorized into three subgroups (Table 1): group A (based on the type of surgical method), tympanoplasty vs. canal wall-down tympanoplasty; group B (based on the type of ossicular replacement), partial ossicular replacement prosthesis (PORP) vs. total ossicular replacement prosthesis (TORP) vs. none; group C (based on the type of tympanic membrane repair material), temporalis fascia vs. tragus cartilage.

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.

Table 1 Distribution of cases in different groups.

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 canal wall-down tympanoplasty group showed improvement at every frequency. In the 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 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).

Hearing results and repair material

Both the temporalis fascia and tragus cartilage groups, all frequencies showed significant improvement in AC. Concerning the temporalis fascia group, ABG changes at all frequencies showed a significant improvement, while BC changes significantly improved at all frequencies except 4000 Hz. In the tragus cartilage group, ABG changes at all frequencies except 2000 Hz significantly improved, BC changes were not significant at 250 ($P = .224$) and 4000 Hz ($P = .807$) (Fig 4).

Fig 4 Analysis of the types of repair material (tragus cartilage vs. temporalis fascia).

Discussion

This study compared pre-and postoperative frequency-specific hearing outcomes in patients with COM. Of the total cohort, hearing in all frequencies improved significantly postoperatively in AC and ABG test, as expected. The gain is most prominent at low and middle frequencies. This is consistent with previous studies [2]. The normal middle ear pressure gain (a result of ossicular coupling) is frequency-dependent [3]. As noted by Choi HG et al. that the mean gain decreases 6 dB or less per octave for frequencies above 1000 Hz [1]. 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. Perforation of the tympanic membrane, disruption or fixation of the ossicular chain, change of round window membrane, tympanosclerosis, and fixation of stapes can all cause an elevation in BC [4]. Except for 250 and 4000 Hz, the present study identified that BC improved significantly 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 [5-6].

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[7]. Furthermore, Quaranta et al. claimed that an intact posterior canal wall was considered a predictor of the better hearing result in ossiculoplasty [8]. 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[2]. It was perhaps relevant that the intact ossicular chain has the greatest impact on hearing at 2000 Hz [9]. 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)[10]. 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.

Sound propagation is influenced by the shape, thickness, and anisotropy of the tympanic membrane [11]. Most studies show no statistical difference in postoperative hearing improvement with different repair materials. However, they only evaluated the average pure tone threshold. This would tend to obscure fine differences in a specific frequency [12]. The AC and ABG statistical results demonstrated that the hearing improvement in the tragus cartilage group was better from 250 to 1000 Hz, but the temporalis fascia group was significantly better from 2000 to 4000 Hz. The rigid nature of tragus cartilage can effective in preventing retraction and resisting negative pressure in the middle ear cavity[13]. A study by Gan RZ et al. found that the stapes footplate displacement amplitude obtained by tragus cartilage was greater than that obtained by temporalis fascia in the low frequency areas (250-1000 Hz), with better postoperative hearing results[14]. Others, in contrast to our findings, claim that stiffer graft materials improve high-frequency sound conduction but worsen low-frequency sound conduction [15]. As far as we known, the temporal fascia was mainly used for tympanic membrane reconstruction with normal ventilatory function, while tragus cartilage was especially suitable for Eustachian tube dysfunction, adhesion, recurrence of the case [16]. A slight deterioration in BC was observed in the temporalis fascia group at 4000 Hz, but the sensorineural hearing loss was unrelated of the type of graft used during reconstruction [17].

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[1]. They suggest that the stapes suprastructure plays an important role in hearing [18], 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 [19]. 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[20]. Similarly, we discovered that three groups all showed significantly improved at 1000-2000 Hz.

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.

Keypoints

*The hearing improved significantly postoperatively in AC and ABG test, mainly at low and mid frequencies.

*The hearing improvement in the tragus cartilage group was better from 250 to 1000 Hz, but the temporalis fascia group was significantly better from 2000 to 4000 Hz.

*The TORP group had the best hearing improvement.

*The canal wall-down tympanoplasty group had poorer postoperative BC outcomes compared to the tympanoplasty group at 4000 Hz.

*The influence of ossicular chain mechanics on BC is expressed at most as the improvement for the frequency of 2000 Hz.

Compliance with ethical standards

Conflicts of interest The authors declares that they has no conflict of interest.

Ethical approval All procedures performed in this study involving human participants were following the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments.

Informed consent This was retrospective study, thus no informed consent was 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 PORP,n None,n Repair material Temporalis fascia,n Tragus cartilage,n	17(9.8) 107(61.8) 49 (28.3) 39(22.5) 134(77.5)

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.

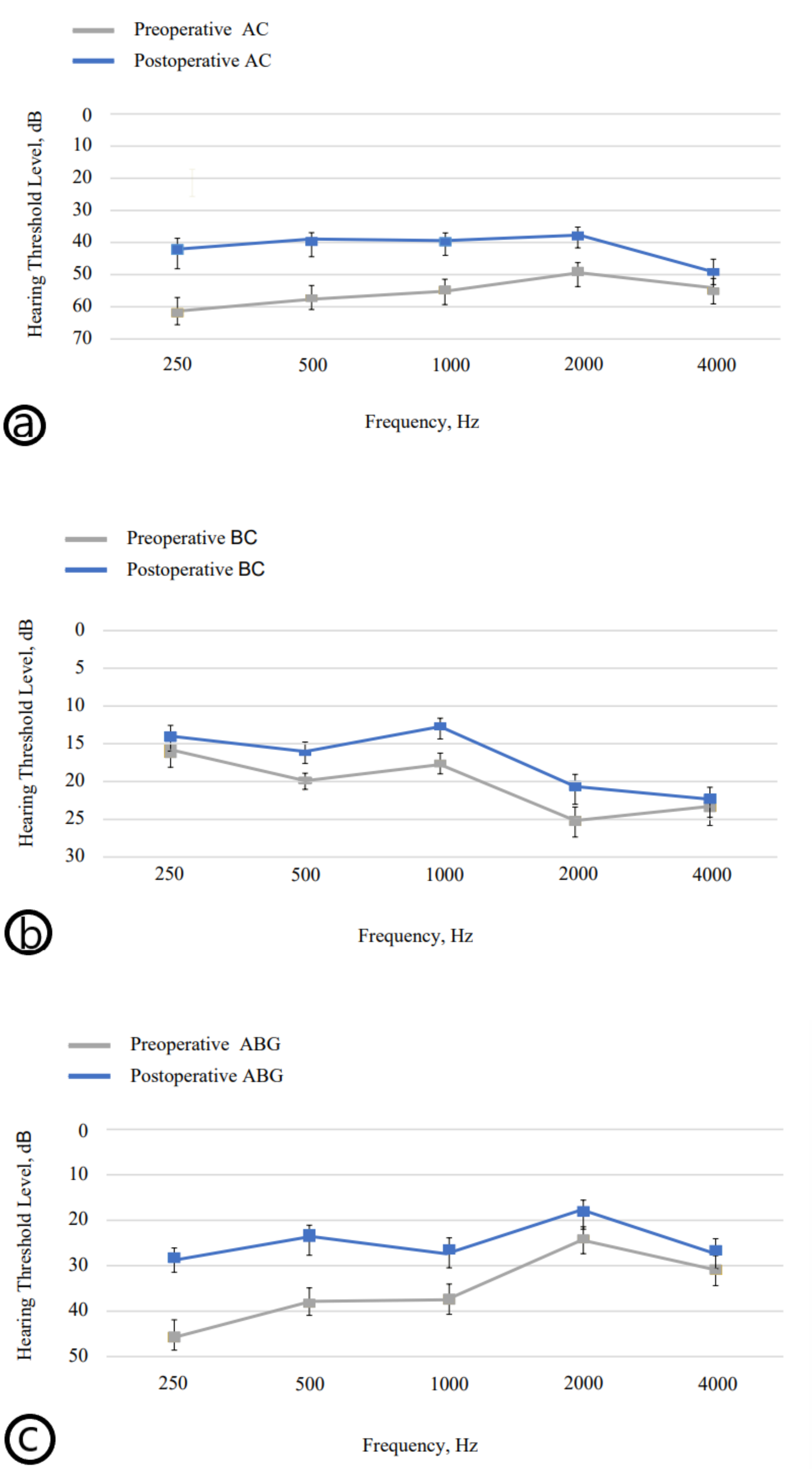

Fig 2 Analysis by surgical methods (tympanoplasty vs. canal wall-down tympanoplasty).

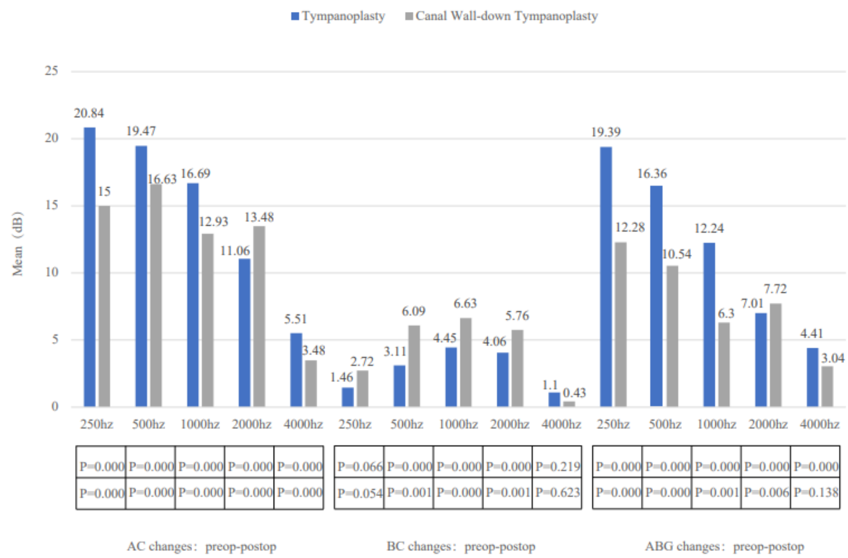

Fig 3 Analysis of the types of ossicular replacement (None vs. TORP vs. PORP).

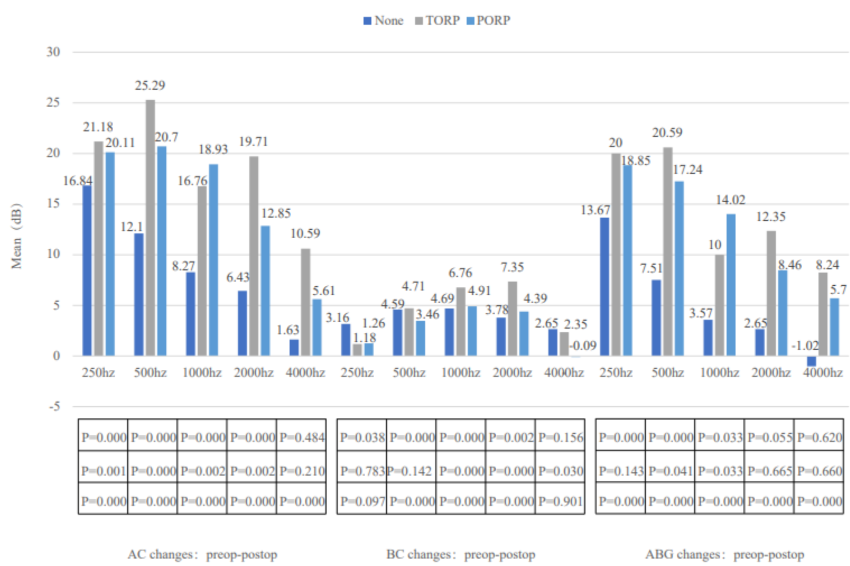

Fig 4 Analysis of the types of repair material (tragus cartilage vs. temporalis fascia).

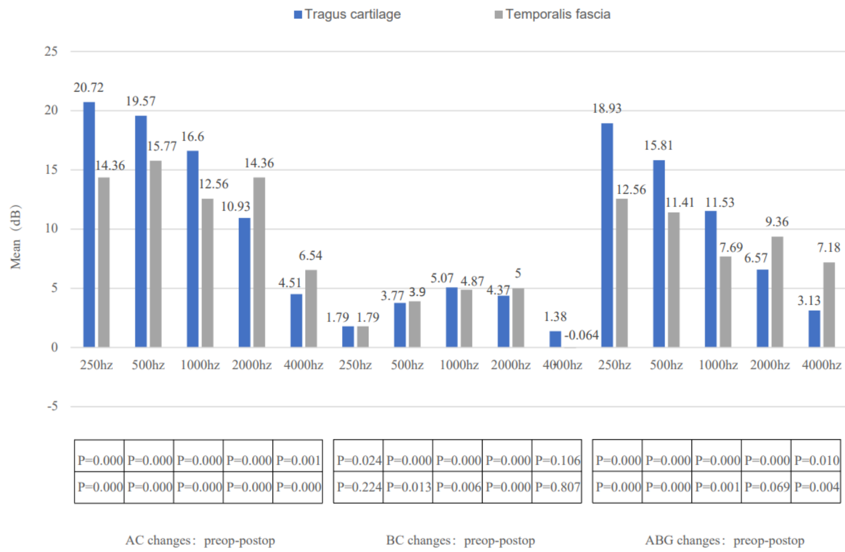

Figure legends

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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