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OTOLOGY

Operative findings of conductive hearing loss with intact tympanic membrane and normal temporal bone computed tomography

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Abstract Despite recent technological advances in diagnostic methods including imaging technology, it is often difficult to establish a preoperative diagnosis of conductive hearing loss (CHL) in patients with an intact tympanic membrane (TM). Especially, in patients with a normal temporal bone computed tomography (TBCT), preoperative diagnosis is more difficult. We investigated middle ear disorders encountered in patients with CHL involving an intact TM and normal TBCT. We also analyzed the surgical results with special reference to the pathology. We reviewed the medical records of 365 patients with intact TM, who underwent exploratory tympanotomy for CHL. Fifty nine patients (67 ears, eight bilateral surgeries) had a normal preoperative TBCT findings reported by neuroradiologists. Demographic data, otologic history, TM findings, preoperative imaging findings, intraoperative findings, and pre- and postoperative audiologic data were obtained and analyzed. Exploration was performed mostfrequently in the second and fifth decades. The most common postoperative diagnosis was stapedial fixation with non-progressive hearing loss. The most commonly performed hearing-restoring procedure was stapedotomy with piston wire prosthesis insertion. Various types of hearing-restoring procedures during exploration resulted in effective hearing improvement, especially with better outcome in the ossicular chain fixation group. In patients with CHL who have intact TM and normal TBCT, we should consider an exploratory tympanotomy for exact diagnosis and hearing improvement. Information of the common operative findings from this study may help in preoperative counseling.

Keywords Conductive hearing loss · Operative surgical procedure · Computed tomography

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Introduction

Despite recent technological advances in diagnostic methods including imaging technology, it is often difficult to establish a reliable preoperative diagnosis in a patient with a conductive hearing loss (CHL). Especially, in a patient with an intact tympanic membrane (TM) and a normal temporal bone computed tomography (TBCT), we can only assume the etiology to be a most frequent condition such as infraradiologic otosclerosis (OS). Although a variety of investigations including video pneumatic otoscopy [1], multifrequency tympanometry [2], and sweep frequency tympanometry [3] have been advocated to explore the cause of an unexplained CHL, none of these techniques has a sufficient sensitivity and specificity to allow a reliable diagnosis to be made in all cases. Otologists frequently rely on an exploratory tympanotomy to establish an exact diagnosis and to allow for correction of the CHL.

In this study, we aimed to demonstrate the middle ear pathologies encountered during exploratory tympanotomy

in patients who have a CHL, with intact TM and normal TBCT. We also analyzed the surgical results with special reference to middle ear disorders.

Materials and methods

This study protocol was approved by the Institutional Ethics Committee at the Samsung Medical Center.

Study design and setting

We reviewed the medical records of 363 patients with intact TM, who underwent exploratory tympanotomy for CHL in the Department of Otorhinolaryngology-Head and Neck Surgery at Samsung Medical Center between December 1995 and July 2010. Ninety-one patients (total 101 ears, 10 bilateral surgeries) had normal preoperative TBCT findings, which were confirmed by experienced neuro-radiologists. Afterward, the radiologists reviewed their TBCT reports again after knowing that the cases had audiometric air–bone gap (ABG) in the absence of TM abnormality to find the possible etiologies including the ossicular anomaly and superior semicircular canal dehiscence (SSCD) syndrome [4]. As a result, 32 patients (two bilateral cases) were proven to be abnormal by TBCT and were excluded. Finally, the medical records of 59 patients (total 67 ears, eight bilateral surgeries) were reviewed retrospectively. Intraoperative findings of the exploratory tympanotomy and the information of performed hearing-restoring procedures was collected and analyzed.

Audiometric testing

Air and bone conduction thresholds were determined with a model GSI 61 clinical audiometer (Grason-Stadler Inc., Madison, WI, USA) calibrated according to the ISO standards. Four-tone pure-tone averages of the mean of the thresholds at frequencies of 0.5, 1, 2, and 3 kHz and ABG were calculated pre- and postoperatively according to the guidelines of the American Academy of Otolaryngology-Head and Neck Surgery. Postoperative audiometric data were obtained from the most recent tests, which were implemented at least 6 months after surgery.

Radiologic imaging

Before surgery, all patients underwent high-resolution TBCT with a Siemens Sensation multi-detector CT scanner. The images were obtained with helical acquisition with 0.6 mm collimation of the X-ray beam and 0.3 mm incremental reconstructions in the axial and coronal planes, yielding a pixel dimension of 0.137 mm^2 and a voxel dimension of 0.0822 mm^3. The reconstructed slice thickness was 0.625 mm.

Exclusion criteria

To exclude confounding factors that might influence the hearing outcomes, the following exclusion criteria were used: grossly abnormal TM findings, history of previous otologic surgery, and the presence of auricular or external auditory canal anomalies. In addition, patients without the required audiometric and radiologic data including formal reading from radiologists, and patients with a time interval over 1 year between TBCT and the operation were also excluded.

Surgical technique

All operations utilized an endaural approach. After endaural incision, tympanomeatal flap elevation and exploration of the middle ear cavity were performed. Thorough examination of the ossicles, facial nerve, round window (RW), and oval window (OW) were undertaken. The subsequent operative procedures included removal of the abnormal ossicles, stapedial suprastructure remnants, mucosal band between the incus and stapes. For ossicular chain reconstruction, stapedotomy with Teflon® piston wire prothesis (PWP), ossiculoplasties such as total ossicular replacement (TOR), partial ossicular replacement (POR), long columellization (LC), and short columellization (SC) with autologous cartilage were performed. In some cases, ossicular mobilization (e.g., ankylosis removal) was performed. Finally, the tympanomeatal flap was repositioned and external auditory canal (EAC) packing was done with Gelfoam® (absorbable gelatin sponge).

Statistical analyses

Statistical analyses were performed using the SPSS version 18.0 (SPSS, Chicago, IL, USA). Fischer's exact test and the Mann–Whitney's *U* test were applied to compare the variables of the two groups. Wilcoxon's signed rank test was used to compare pre- and postoperative hearing results. Values are presented as mean ± SD. A p value <0.05 was considered to be statistically significant.

Results

Fifty-nine eligible patients (67 ears) were included in this study. Thirty-one patients were male and 28 were female. Eight patients (two males and six females) underwent bilateral exploratory tympanotomy. The mean age at

surgery was 33.2 years (range, 8–70 years), most frequently in the second decade (17 ears, 25.3 %) and the fifth decade (16 ears, 23.9 %). The patients with ossicular chain fixation (OF; $n = 57$ ears) underwent operation most frequently during the fifth decade (16 ears, 28.1 %). Patients with ossicular discontinuity (OD; $n = 9$ ears) most often were operated on during their second decade (four ears, 44.4 %) (Fig. 1).

Intraoperative findings

The operative findings are summarized in Table 1. From surgical microscopic examinations, the number of ears with OF, OD, and the combined ossicular fixation and discontinuity (OFD) were 57 (85.1 %), 9 (13.4 %), and 1 (1.5 %) ears, respectively.

Causes of OF

The causes of OF are summarized in Table 1. In the OF group of 57 patients, the presence of OF and the absence of OD were confirmed from the intraoperative findings. The most frequent cause of OF was stapedial fixation with non-progressive hearing loss (37 ears, 55.2 %), followed by stapedial fixation with progressive hearing loss (12 ears, 17.9 %), fixed malleus and incus (six ears, 9.0 %), and fixed malleus, incus, and stapes (two ears, 3.0 %).

Causes of OD

The causes of OD are also summarized in Table 1. In the OD group of nine patients, both stapedial mobility and round window reflex were confirmed from intraoperative findings. The causes of OD include eroded lenticular process of the incus (four ears, 6.0 %), fracture of the stapedial suprastructure with traumatic history (three ears, 4.5 %), and eroded a part of incus and stapes (two ears, 3.0 %). OD categorization was consistent with a previous study [5].

Table 1 Intraoperative findings according to the type of pathology

Most likely diagnosis	Ears ($n = 67$)	%
Ossicular chain fixation (OF)	57	85.1
Stapedial fixation with non-progressive hearing loss	37	55.2
Stapedial fixation with progressive hearing loss	12	17.9
Fixed malleus and incus	6	9.0
Fixed malleus, incus and stapes	2	3.0
Ossicular discontinuity (OD)	9	13.4
Eroded lenticular process of incus (with mucosal band between incus and stapes)	4 (1)	6.0 (1.5)
Fracture of ossicular chain by trauma (fracture of stapedial suprastructure)	3	4.5
Eroded incus and stapes (oval window agenesis)	2	3.0
Ossicular fixation and ossicular discontinuity (OFD)	1	1.5
Total	67	100

Case of combined OFD

The sole case of OFD, with combined OF and OD (1.5 %), displayed an anomalous stapedial suprastructure, fixed stapedial footplate, and subtle erosion of the lenticular process of the incus.

Hearing-restoring procedures

For improvement of hearing, various hearing-restoring procedures were implemented in most patients (Fig. 2).

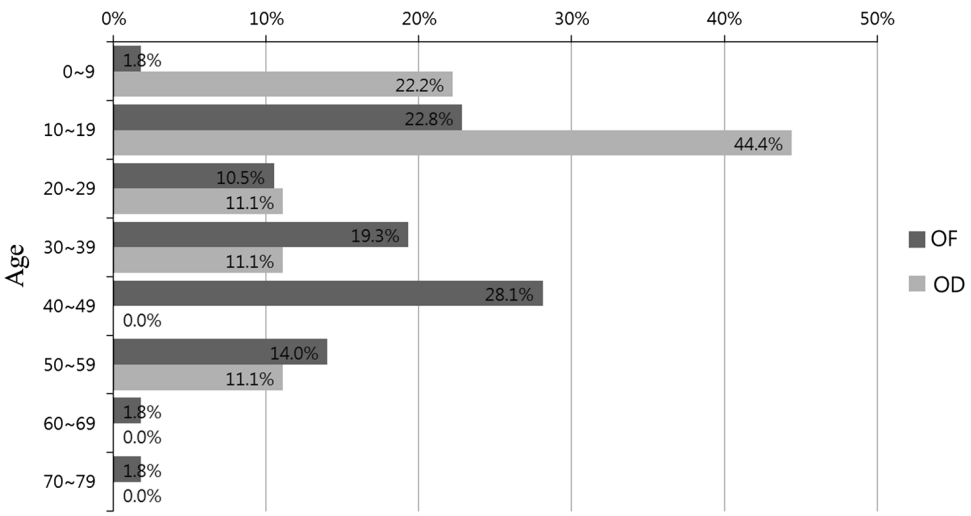

Fig. 1 The average age at surgery in the ossicular chain fixation (OF) and ossicular discontinuity (OD) groups

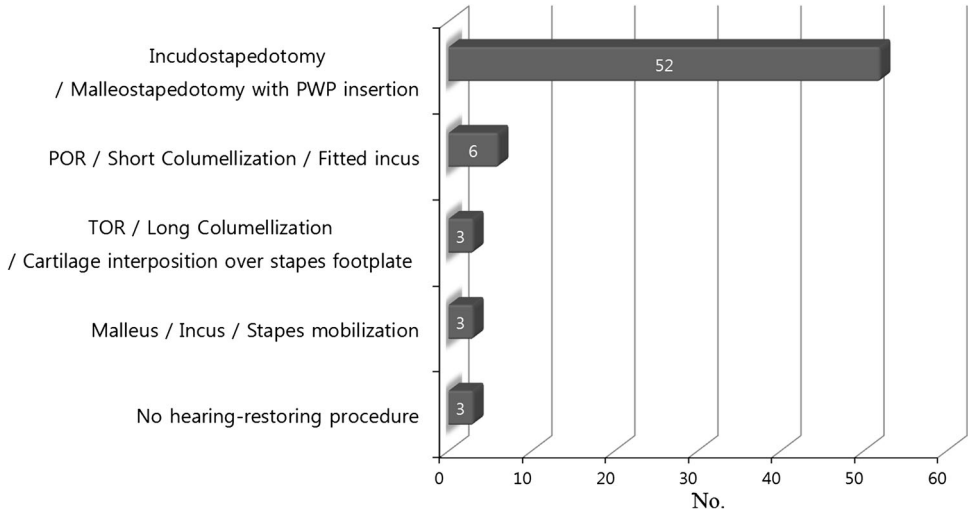

Fig. 2 The various types of hearing-restoring procedures performed during exploratory tympanotomy

Incudo-stapedotomy or malleo-stapedotomy with PWP insertion (52 ears) was the most frequently used procedure. POR/SC and TOR/LC were carried out in six ears and three ears, respectively. In three ears, mobilization of fixed ossicle was performed. Three ears did not receive any hearing-restoring procedure due to the aberrant course of the facial nerve and oval window agenesis.

Pre- and postoperative hearing results

The pre- and postoperative average air-conduction threshold irrespective of the types of pathology was 52.7 ± 14.1 and 35.4 ± 16.6 dB, respectively, and this result showed statistically significant hearing gain ($p < 0.0001$). In terms of ABG, hearing outcome was qualified as "very good" (ABG closure to within 10 dB) for 32 ears (47.8 %), "good" (ABG closure from 10–20 dB) for 22 ears (32.8 %), "acceptable" (ABG closure from 20–30 dB) for 10 ears (14.9 %), and "bad" (ABG, ≥30 dB) for 3 ears (4.5 %) (Fig. 3a). The average ABG improved from 28.1 ± 10.3 to 13.7 ± 9.4 dB postoperatively ($p < 0.0001$).

Four out of 76 ears (two ears in OF and two ears in OD) showed an increased ABG after exploration, with an average of 8.4 dB (from 3.75 to 13.75 dB).

Figure 3b shows pre- and postoperative hearing results according to the types of pathology. Of 67 ears, the OF group ($n = 57$) showed significant hearing gain in ABG (26.7 ± 9.4 versus 12.1 ± 7.0 dB; $p < 0.0001$). However, nine ears with OD demonstrated smaller hearing gain in ABG (36.3 ± 12.7 versus 25.5 ± 13.7 dB; $p = 0.085$). Preoperatively, ABG between the OF group and the OD group showed a statistically significant difference (26.7 ± 9.4 versus 36.3 ± 12.7 dB; $p = 0.0018$), and postoperative ABG showed a better result in the OF group than in the OD group (12.1 ± 7.0 versus 25.6 ± 13.7 dB; $p = 0.0018$). This result shows that the OF group has smaller preoperative ABG and higher chance of hearing improvement than the OD group after hearing-restoration procedures.

Discussion

The aims of this retrospective analysis were (1) to describe the types of pathology encountered in patients who have a CHL with intact TM and a normal TBCT in the formal report by radiologists and (2) to analyze the surgical results by audiologic data with special reference to the ossicular status. Preoperative investigations such as otoscopy, audiometry, tympanometry, and high-resolution TBCT scanning are helpful but cannot provide reliable clues for patients in this category [5].

Several studies have explored exploratory tympanotomy for CHL [5–8]. However, these reports were descriptive analyses of intraoperative findings of exploratory tympanotomy for CHL with intact TM, irrespective of TBCT scan findings. A normal TBCT is not infrequently encountered in the evaluation of these patients, and the etiologies that cause a CHL is an important issue in the clinic for preoperative counseling.

In our series, the most common intraoperative finding was OF (57 of 67 ears, 85.1 %), which was markedly higher than that reported previously (192 of 340 ears, 56.5 %) [5]. The previous study included patients' data irrespective of TBCT findings; the most common cause of OF was OS (164 of 192 ears, 85.4 %), whereas stapedial fixation with non-progressive hearing loss was the most common cause of OF in our study (37 of 57 ears, 64.9 %). This difference may well have been the result of the technical advance of TBCT that has occurred in the time between the previous and present studies. Presently, most cases of OS were diagnosed preoperatively and were excluded. OD was the second most common

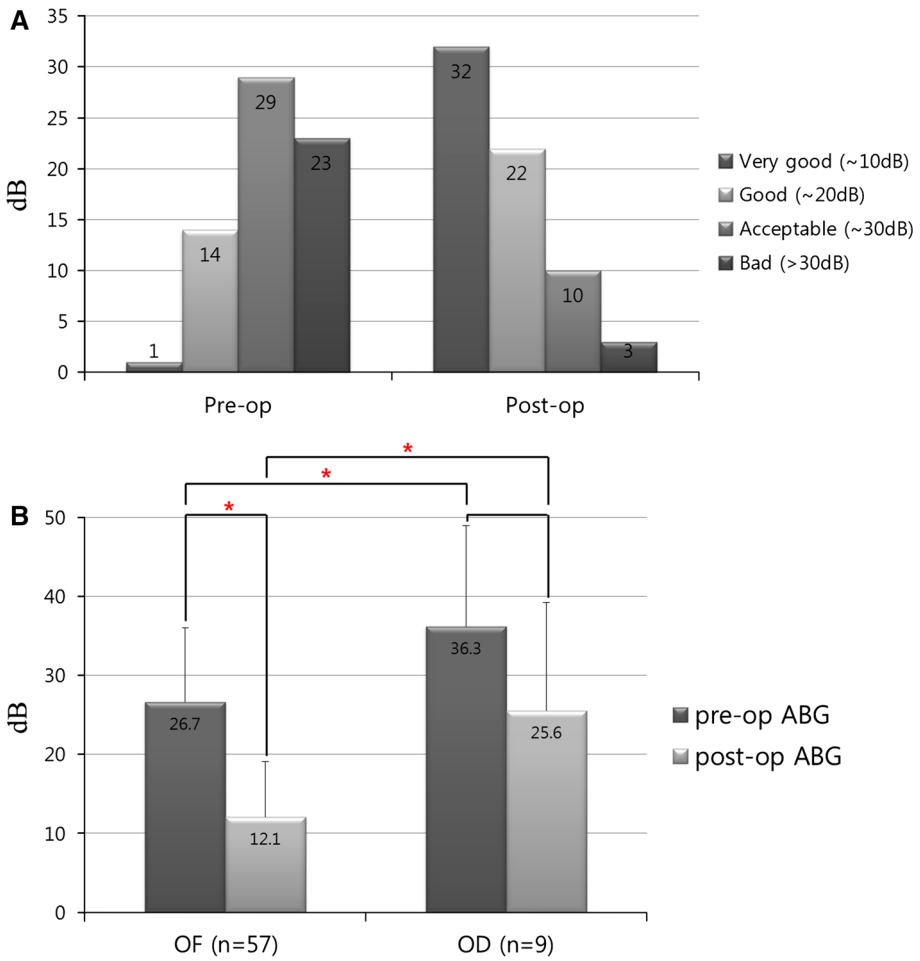

Fig. 3 Decibel hearing level in the pre- and postoperative period. "Very good" indicates air–bone gap (ABG) closure of 10 dB or lower; "good," ABG of 11–20 dB; "acceptable," ABG of 21–30 dB; and "bad," ABG higher than 30 dB (**a**). The pre- and postoperative hearing results according to the type of pathology (**b**). *Error bars* represent standard error of the mean; *asterisks* denote statistically significant difference ($p < 0.05$)

intraoperative finding in our series (9 of 67 ears, 13.4 %). As OD is relatively easy to detect in TBCT, the proportion was smaller than that in the previous report (103 of 340 ears, 30.3 %) [5].

A recent study reported a 73 % positive rate of TBCT for OS [9]. In another study [10], 15 negative CT scans included four minor malformations of the ossicular chain, one fracture of the stapes, and ten cases (66.6 %) of infraradiologic forms of OS were reported. In the latter study, the preoperative sensitivity of HRCT scan in the diagnosis of OS was 95.1 % and its specificity was 99.5 %. In our series of 67 ears with a negative TBCT finding, 12 ears (17.9 %) were assumed as infraradiologic forms of OS presenting with a propensity of progressive hearing loss.

Bachor et al. [11] reported that children younger than 6 years with various congenital anomalies were more likely to have congenital stapedial fixation, which presented intraoperatively as a thickened footplate with a partial or absent annular ligament. The most important characteristics of OS different from the congenital stapes ankylosis are progression of a CHL and a positive family history. Moreover, children older than 6 years with progressive CHL are more likely to have OS, which presents as fixation of the anterior stapediovestibular joint [11]. They suggest that it is important to differentiate preoperatively between OS and congenital stapedial fixation, because surgical results tend to be inferior in congenital stapedial fixation.

In our study, the hearing result was better for OF than OD, as stapedotomy with PWP insertion generally gives a better result than ossiculoplasties including POR/SC and TOR/LC.

The results of this study provide information on the pathologic findings of CHL patients with a negative CT finding, which can be used for preoperative counseling. An exploratory tympanotomy should be recommended for the exact diagnosis and hearing improvement for this group of patients.

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Conflict of interest None.

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