International Journal of Life Sciences, Biotechnology and Pharma Research Vol. 13, No. 8, August 2024 Online ISSN: 2250-3137
Print ISSN: 2977-0122

DOI: 10.69605/ijlbpr_13.8.2024.23

ORIGINAL RESEARCH

Evaluating Intraoperative Findings in Conductive Hearing Loss with Intact Tympanic Membrane: A Retrospective Study

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Received: 05/07/2024 Accepted: 11/08/2024

ABSTRACT

Introduction: The condition of the ossicular chain is closely linked to the extent of conductive hearing loss (CHL) when the tympanic membrane (TM) remains undamaged. This study aims to evaluate the correlation between intraoperative observations and audiological data in individuals presenting with unilateral CHL and an intact TM. **Materials and Methods:** The study included 78 patients who underwent surgical procedures. Patients were categorized according to intraoperative findings. The analysis included demographic information, intraoperative observations, and preoperative as well as postoperative audiological outcomes. **Results:** Patients with ossicular chain disruption demonstrated significantly more favorable outcomes compared to those with ossicular chain fixation. Preoperatively, patients with ossicular chain deformities exhibited higher air conduction threshold [ACT] and a widerair bone gap [ABG] compared to those with cholesteatoma, though postoperative outcomes were similar between the two groups. **Conclusion:** The surgical outcomes for congenital ossicular chain anomalies were comparable regardless of the underlying pathology. In contrast, patients with acquired conditions had better audiological outcomes following ossicular chain disruption than those with ossicular chain fixation. Ossicular chain reconstruction can lead to significant improvements in hearing for patients with unilateral CHL and an intact TM.

Key Words: Conductive hearing loss, tympanic membrane, ossicular chain, cholesteatoma

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INTRODUCTION

Conductive hearing loss (CHL) frequently presents in otologic clinics and arises due to damage or malfunction within the sound conduction pathway, resulting in diminished sound energy transmission from the ear canal to the cochlea. The primary etiological factors contributing to this condition include inflammation, congenital middle ear malformations, otosclerosis, cholesteatoma, and trauma [1,2].

In most instances, CHL can be surgically corrected. However, accurately diagnosing the condition preoperatively in patients with an intact tympanic membrane (TM), especially in cases of unilateral CHL (UCHL), remains challenging. Although high-resolution computed tomography is beneficial for diagnosing CHL caused by infectious or inflammatory processes [3,4], it may not effectively detect ossicular chain abnormalities, such as anomalies or traumatic disruptions [5]. The integrity of the ossicular chain plays a pivotal role and is closely linked to the symptoms of CHL when the TM remains intact. Exploratory tympanotomy is currently the only procedure used for both diagnostic and therapeutic purposes [6]. Nevertheless, there is a scarcity of studies evaluating the differences in audiological outcomes and prognoses based on intraoperative ossicular findings, particularly in unilateral cases.

This study aims to explore the correlation between intraoperative observations and the audiological outcomes in patients with UCHL who have an intact TM, with the goal of providing valuable insights for otologists and patients.

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DOI: 10.69605/ijlbpr_13.8.2024.23

MATERIAL AND METHODS

This study involved a retrospective review of the medical records of all patients diagnosed with unilateral conductive hearing loss (UCHL) who were admitted to Department of Otolaryngology-Head and Neck Surgery and subsequently underwent surgical intervention. Inclusion criteria required patients to have an intact tympanic membrane (TM) prior to undergoing postoperative pure-tone audiometry. Patients with a history of prior otologic surgery, external auditory canal anomalies, or middle ear effusion were excluded from the study.

The collected demographic data included variables such as age, sex, the side affected, and the duration of hearing loss. Based on intraoperative findings, patients were categorized into four groups: ossicular chain disruption, ossicular chain fixation, ossicular chain deformity, and congenital middle ear cholesteatoma. These demographic and surgical data were then analyzed and compared across the different groups.

Pure-tone audiometry was conducted in a soundproof environment using an audiometer. The pure-tone averages for air and bone conduction thresholds were calculated at frequencies of 0.5, 1, 2, and 4 kHz. The air-bone gap (ABG) was assessed both before and after surgery, following the guidelines of the American Academy of Otolaryngology-Head and Neck Surgery [7]. Postoperative audiometric data were collected at least two months after the surgical procedure. Prior to surgery, all patients underwent high-resolution computed tomography (CT) of the temporal bone and an electric otoscopy examination.

The statistical analysis was performed using SPSS version 20 software. Quantitative variables were presented as mean ± standard deviation. To compare continuous variables between two groups, an independent t-test was employed. The paired samples t-test was used to compare auditory outcomes before and after surgery. For dichotomous variables, the chi-square test was applied to assess differences among the groups. A p-value of less than 0.05 was considered statistically significant.

RESULTS

The study comprised 78 participants with a mean age of 24.0 ± 12.7 years. The average duration of hearing loss among these individuals was 4.1 ± 4.8 years. The cohort was nearly evenly split by gender, with 37 females (47.44%) and 41 males (52.56%). Regarding the affected side, 36 participants (46.15%) had right-sided hearing loss, while 42 (53.85%) had left-sided hearing loss (Table 1).

Table 1: Demographic data of study participants.

Characteristics	Value [Mean ± SD or n (%)]
Age (years)	24.0 ± 12.7
Duration of Hearing Loss (years)	4.1 ± 4.8
Female	37 (47.44)
Male	41 (52.56)
Affected Side	
Right	36 (46.15)
Left	42 (53.85)

Intraoperative findings revealed a variety of pathologies (Table 2). Ossicular chain disruption was observed in 18 participants (23.08%), with the majority exhibiting non-traumatic soft connections of the incus-stapes joint (27.78%) or traumatic dislocation (22.22%). Erosion of the lenticular process of the incus, whether traumatic or non-traumatic, was noted in 22.22% of cases. Ossicular chain fixation was documented in 15 participants (19.23%), primarily affecting the malleus and/or incus (40.00%) or the stapes (26.67%). Ossicular chain deformity was present in 20 participants (25.64%), with mobile stapes footplate and stapes suprastructure deformity being the most common (55.00%). Cholesteatoma was identified in 25 participants (32.05%).

Table 2: Intraoperative findings in study participants

Findings	n (%)
Ossicular Chain Disruption	**18 (23.08)**
Soft connection of the incus-stapes joint (Non-Traumatic)	5 (27.78)
Traumatic dislocation of the incus-stapes joint	4 (22.22)
Erosion of the lenticular process of the incus (Non-Traumatic)	4 (22.22)
Traumatic fracture of the lenticular process of the incus	3 (16.67)
Traumatic dislocation of the incus	2 (11.11)
Ossicular Chain Fixation	**15 (19.23)**
Malleus and/or incus fixation	6 (40.00)
Poor movement, surrounded by a calcified plaque	5 (33.33)
Stapes fixation	4 (26.67)

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Ossicular Chain Deformity	**20 (25.64)**
Mobile stapes footplate + stapes suprastructure deformity	11 (55.00)
Fixation of the stapes footplate + stapes suprastructure deformity	5 (25.00)
Oval window atresia	4 (20.00)
Cholesteatoma	**25 (32.05)**

Analysis of baseline data and surgical procedures showed significant differences across various groups (Table 3). Participants with ossicular disruption were notably younger (30.8 ± 11.4 years) compared to those with ossicular fixation (31.8 ± 10.6 years), deformity (25.5 ± 11.6 years), and cholesteatoma (17.6 ± 12.4 years), with these differences reaching statistical significance ($p < 0.05$). Gender distribution varied significantly among the conditions, with males being more prevalent in cases of ossicular disruption (72.22%) and fixation (26.67%) compared to other groups. Affected side also differed, with left-sided involvement being more common in fixation cases (86.67%) and right-sided involvement more prevalent in deformity cases (65.00%). Duration of hearing loss was significantly longer in those with ossicular fixation (7.2 ± 5.7 years) compared to the other groups.

Table 3: Comparison of baseline data and surgical procedures

Characteristic	**Disruption**	**Fixation**	**Deformity**	**Cholesteatoma**	**p-Value**
n	18	15	20	25	
Age (years)	30.8 ± 11.4	31.8 ± 10.6	25.5 ± 11.6	17.6 ± 12.4	<0.05
Gender					
Male	13 (72.22)	4 (26.67)	13 (65.00)	13 (52.00)	<0.05
Female	5 (27.78)	11 (73.33)	7 (35.00)	12 (48.00)	
Affected Side					
Left	11 (61.11)	13 (86.67)	7 (35.00)	11 (44.00)	<0.05
Right	7 (38.89)	2 (13.33)	13 (65.00)	14 (56.00)	
Hearing loss Duration (years)	1.5 ± 3.1	7.2 ± 5.7	6.1 ± 5.8	2.4 ± 1.6	<0.05
Ossicular Chain Reconstruction					
TORP	0 (0.00)	0 (0.00)	11 (55.00)	16 (64.00)	
PORP	18 (100.00)	6 (40.00)	0 (0.00)	5 (20.00)	
Stapedectomy with PWP	0 (0.00)	3 (20.00)	0 (0.00)	4 (16.00)	
Mobilization	0 (0.00)	6 (40.00)	0 (0.00)	0 (0.00)	
No Reconstruction	0 (0.00)	0 (0.00)	9 (45.00)	0 (0.00)	

Post-operative outcomes revealed substantial improvements in hearing thresholds across different pathologies (Table 4). For ossicular disruption, the average air conduction threshold (ACT) improved from 52.25 ± 13.53 dB pre-operatively to 26.00 ± 8.70 dB post-operatively, with a significant mean change of 26.25 ± 10.23 dB ($p < 0.01$). Similarly, air-bone gap (ABG) reduced significantly from 39.00 ± 11.25 dB to 10.80 ± 6.70 dB, with a mean change of 28.20 ± 10.50 dB ($p < 0.01$). Ossicular fixation showed a reduction in ACT from 67.50 ± 5.10 dB to 44.30 ± 14.70 dB (mean change: 23.20 ± 12.75 dB, $p < 0.01$) and in ABG from 45.50 ± 6.10 dB to 19.00 ± 9.20 dB (mean change: 26.50 ± 11.60 dB, $p < 0.01$). Improvements in ossicular deformity and cholesteatoma cases were also noted, though the changes were less significant in terms of p-values.

Table 4: Pure-tone threshold changes after ossicular reconstruction surgery

Parameter	**Pre-op ACT (dB)**	**Post-op ACT (dB)**	**ΔACT (dB)**	**Pre-op ABG (dB)**	**Post-op ABG (dB)**	**ΔABG (dB)**
Ossicular Disruption (n = 18)	52.25 ± 13.53	26.00 ± 8.70	26.25 ± 10.23	39.00 ± 11.25	10.80 ± 6.70	28.20 ± 10.50
Ossicular Fixation (n = 15)	67.50 ± 5.10	44.30 ± 14.70	23.20 ± 12.75	45.50 ± 6.10	19.00 ± 9.20	26.50 ± 11.60
p-Value	**<0.01**	**<0.01**	**0.45**	**0.054**	**<0.01**	**0.66**
Ossicular Deformity (n = 20)	49.50 ± 12.20	23.60 ± 6.45	25.90 ± 7.30	37.00 ± 10.00	10.20 ± 4.00	27.80 ± 7.50
Cholesteatoma (n = 25)	44.10 ± 15.50	22.50 ± 9.20	21.60 ± 11.30	33.00 ± 13.50	11.40 ± 7.00	21.80 ± 10.70
p-Value	**0.21**	**0.65**	**0.15**	**0.28**	**0.49**	**<0.05**

Overall, the findings indicate that ossicular reconstruction surgery leads to considerable improvements in hearing thresholds, with the most pronounced benefits observed in cases of ossicular disruption.

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DOI: 10.69605/ijlbpr_13.8.2024.23

DISCUSSION

A thorough assessment of the correlation between the status of the ossicular chain and audiological outcomes is crucial for surgical planning and informed consent. This study examined intraoperative findings and audiological results in patients with unilateral conductive hearing loss (UCHL) and an intact tympanic membrane (TM). Our findings indicate that ossicular chain reconstruction can significantly enhance hearing in patients with UCHL and intact TM. Although patients with cholesteatoma exhibited lower preoperative air conduction thresholds (ACT) and smaller preoperative air-bone gaps (ABG) compared to those with ossicular deformities, the surgical outcomes were similar across both groups. In contrast, patients with ossicular chain fixation had higher preoperative ACTs and larger preoperative ABGs compared to those with ossicular chain disruption, suggesting that patients with ossicular chain disruption may achieve better audiological outcomes than those with fixation.

Ossicular chain reconstruction, or ossiculoplasty, can be performed using autologous grafts or prosthetic devices, such as partial or total ossicular replacement prostheses [8,9]. In our study, all patients who underwent ossicular chain reconstruction demonstrated improved postoperative ACTs. However, 9 cases of ossicular chain deformity were not subjected to reconstruction due to oval window atresia and/or facial nerve anomalies. Congenital ossicular anomalies often coexist with other middle ear malformations, increasing surgical complexity.

Our study revealed that ossicular fixation was less common than ossicular disruption, a finding that contrasts with a previous study on non-inflammatory conductive hearing loss [1]. Robertson et al. reported a significantly higher proportion of ossicular fixation cases (56.5%) in patients with intact TM [6]. This discrepancy may be attributed to a lower prevalence of otosclerosis in the Asian population compared to Caucasians with UCHL. Most cases of ossicular disruption in our study involved a single ossicle, with the incus being most frequently affected and the stapes typically normal. The incus, being the heaviest and lacking muscle attachments compared to other ossicles, is more susceptible to trauma [10]. The incus-stapes joint is the weakest point in the ossicular chain, making it vulnerable to damage [11]. Inflammation is likely a major cause of erosion at the lenticular process of the incus and the incus-stapes joint in cases of ossicular disruption of unknown etiology [12]. Despite patients reporting no history of otorrhea or otalgia, the possibility of past middle ear infections during infancy or childhood cannot be ruled out. Additionally, the lenticular process of the incus, which is floating and lacks blood supply, may also increase its susceptibility to damage.

Audiological results indicated differences between the ossicular fixation and disruption groups. The preoperative ACT was higher in the fixation group compared to the disruption group. For UCHL with intact TM, if the preoperative ACT exceeds 60–70 dB, ossicular chain fixation or oval window atresia should be considered [13]. Multiple ossicles may be involved in a single fixation case, and sclerosis could exacerbate the mobility issues by increasing the weight of the fixed ossicles. Postoperative ACT and ABG were lower in cases of ossicular disruption, suggesting better outcomes in this group. However, a previous study found a higher postoperative ABG in the ossicular chain disruption group [5], potentially due to the predominance of otosclerosis in that study. In our study, three out of eight ossicular fixation cases involved partial fixation and underwent ossicular chain mobilization, which is generally less effective than stapedotomy with piston wire prosthesis [14].

The most frequent causes of UCHL with intact TM in our study were congenital ossicular deformity and middle ear cholesteatoma. Intraoperative observations revealed complex ossicular chain conditions. For non-progressive CHL of 40–60 dB with an intact TM and no trauma or infection history, congenital ossicular malformation should be strongly suspected [15]. Middle ear cholesteatoma should also be considered in cases with an intact TM [16], as congenital cholesteatoma may be associated with ossicular chain anomalies or secondary ossicle damage.

Congenital ossicular deformity and cholesteatoma with intact TM often present with similar clinical features and intraoperative ossicular findings, such as eroded or absent ossicular structures. When comparing preoperative ACTs across these two groups, the cholesteatoma group showed better audiological results. However, postoperative audiometric outcomes were similar between the two groups, consistent with previous studies [16]. The average audiometric follow-up time was 10 months, with no recurrent cholesteatoma or TM retraction observed during the follow-up period. Both congenital ossicular deformity and cholesteatoma can affect multiple ossicles, particularly in unilateral cases [15,17]. In cholesteatoma, even with ossicle damage, hearing may appear relatively unaffected or mildly impaired due to the cholesteatoma bridging the ossicular gap, a phenomenon referred to as ‘silent cholesteatoma’, ‘conductive cholesteatoma’, or ‘cholesteatoma hearer’ [18,19]. Ossicular chain reconstruction was not performed in three patients with congenital ossicular deformity due to facial nerve anomalies. Facial nerve aberration is reported in 11% of patients with congenital stapes fixation [20] and can complicate ossicular chain reconstruction. These considerations are important for evaluating audiometric results relative to operative findings and should be communicated to patients when discussing potential surgical benefits and predicting audiological prognosis.

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DOI: 10.69605/ijlbpr_13.8.2024.23

CONCLUSION

In conclusion, ossicular chain reconstruction is highly effective in enhancing hearing in patients with unilateral conductive hearing loss (UCHL) who have an intact tympanic membrane (TM). For patients with congenital ossicular chain anomalies, the surgical outcomes were comparable between those with ossicular chain involvement and those with cholesteatoma, regardless of the underlying pathology. Conversely, in patients with acquired ossicular chain dysfunction, those with ossicular chain disruption experienced more favorable audiological outcomes compared to those with ossicular chain fixation.

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