MAK HILL Publications Research Journal of Medical Sciences

Research Article
doi: 10.36478/makrjms.2024.5.670.674

Evaluation of Hearing Results Following Ossiculoplasty in Canal Wall Down Tympanoplasty for Middle-Ear Cholesteatoma

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OPEN ACCESS

Key Words
Cholesteatoma, hearing, mastoid, otologic surgical procedures, tympanoplasty

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Received: 3 April 2024
Accepted: 6 May 2024
Published: 13 May 2024

Citation: Falguni Amin, Dweethi Jayaprakash, Arun Yadav and Kinnari K. Rathod, 2024. Evaluation of Hearing Results Following Ossiculoplasty in Canal Wall Down Tympanoplasty for Middle-Ear Cholesteatoma. Res. J. Med. Sci., 18: 670-674, doi: 10.36478/makrjms.2024.5.670.674

Abstract
Cholesteatoma surgery remains a topic of ongoing debate in the medical literature. The optimal objectives of cholesteatoma surgery should aim for the complete eradication of the disease and the maintenance of optimal hearing function, ideally achieved through a single-stage surgical intervention whenever feasible. The primary objective of this investigation was to assess the auditory outcomes of ossiculoplasty within canal wall down tympanoplasty during single-stage middle-ear cholesteatoma surgery. We conducted a retrospective analysis of a consecutive cohort comprising 178 cases that had undergone canal wall down tympanoplasty with ossicular reconstruction due to chronic otitis media complicated by cholesteatoma. Cholesteatoma were surgically managed in a single-stage procedure under general anesthesia using a retro auricular approach. The surgical process involved removal of cholesteatomas from the outer ear canal, followed by atticotomy, antrotomy and mastoidectomy with canal wall down tympanoplasty. Preoperative audiometric assessments indicated an average air conduction pure tone average (PTA) of 48.42 dB and an average bone conduction PTA of 21.03 dB. Postoperatively, the mean air conduction PTA was 36.65 dB, while the bone conduction PTA averaged 23.09 dB. The average pre-and postoperative air-bone gaps (ABGs) were 29.28 dB and 13.24 dB, respectively, resulting in a gain of 16.04 dB. Notably, approximately 70% of patients achieved ABG closure within 20 dB. Our study suggests that cartilage placed above the prosthesis between stapes or stapes footplate in canal wall down mastoidectomy may improve Hearing. Failures may result from insufficient footplate-prosthesis contact or progressive fibrosis in the middle-ear space. Nonetheless, our positive functional outcomes highlight the significance of reconstructing the ossicular chain in these procedures. We recommend further clinical investigations to optimize hearing outcomes in canal wall down tympanoplasty.

INTRODUCTION

Cholesteatoma, a chronic otitis of the middle ear cleft, stems from abnormal proliferation of keratinising squamous epithelium. It comprises acellular keratin debris within the sac and an active matrix that produces enzymes causing bone erosion. Cholesteatoma can be congenital or acquired, the former from embryonic epidermal debris and the latter classified as primary (from a retraction pocket) or secondary (due to epithelial migration from tympanic perforation, trauma, or surgery). Diagnosis relies on clinical symptoms, otoscopic findings and imaging, with surgery as the definitive treatment, conservative management is considered for patients unfit for general anesthesia[1].

Cholesteatoma surgery remains a topic of active debate within medical literature. The primary objectives of cholesteatoma surgery should aim for complete disease removal while preserving optimal hearing, ideally accomplished in a single surgical intervention if feasible[2].

Initially, radical mastoidectomy was widely practiced to eradicate the disease, albeit at the expense of hearing function. However, advancements in middle-ear reconstructive techniques have provided alternatives. Tympanoplasty with an intact posterior canal wall was initially predominant[3], but canal wall down tympanoplasty has gained traction in recent times[4-6]. The audiological benefits of canal wall up versus canal wall down tympanoplasty, regarding ear safety and disease recurrence, have been extensively debated and acknowledged in literature.

Traditionally, canal wall down procedures struggled to restore auditory function adequately due to structural changes affecting the middle ear's natural space, particularly the loss of the posterior auditory canal wall. Yet, recent years have witnessed the development of several techniques preserving both the middle-ear cavity and sound transmission functionality.

Various biocompatible substitute materials are now available for ossiculoplasty, including autogenous structures (ossicles, cortical bone and cartilage) and allogenous tissues (ossicles, cortical bone, cartilage, and dentin). Autologous ossicles and cartilage are preferred for ossiculoplasty due to cortical bone's resorption over time. In cases where autologous ossicles are unavailable, diverse prostheses, both biological (homologous costal cartilage, cortical mastoid bone and homologous ossicles) and synthetic (Plastipore, hydroxy apatite, gold, titanium, etc.) can be utilized.

This retrospective study aimed to assess long-term hearing outcomes post the use of autogenous and synthetic prostheses in partial and total ossicular chain reconstruction during canal wall down tympanoplasty for middle-ear cholesteatoma.

MATERIAL AND METHODS

A retrospective analysis was conducted involving 178 patients diagnosed with chronic otitis media complicated by cholesteatoma. These patients underwent canal wall down tympanoplasty with ossicular chain reconstruction. The evaluation of hearing outcomes was conducted post-surgery.

Cholesteatomas were surgically managed in a single-stage procedure under general anesthesia using a retro auricular approach. The surgical process involved removal of cholesteatomas from the outer ear canal, followed by atticotomy, antrotomy and mastoidectomy with canal wall down tympanoplasty. The facial ridge was adjusted as necessary without exposing the facial nerve. Ossicular reconstruction was performed using partial ossicular replacement prosthesis (PORP) in patients with intact stapes superstructure (type two tympanoplasty according to Wullstein), or total ossicular replacement prosthesis (TORP) in patients lacking the stapes superstructure (type three tympanoplasty according to Wullstein). In cases with an available incus, careful remodeling was done, while other biological prostheses, especially autologous cartilage grafts, were utilized in cases where the incus was absent or only its residual portion was present. Synthetic prostheses were used selectively, primarily in cases where the facial canal was dehiscent. The malleus handle was not utilized to stabilize the prosthesis and a meatoplasty with cartilage excision was performed in all cases.

The pure tone average (PTA) was calculated as the mean of thresholds at 0.5, 1, 2 and 3 kHz, with the 3 kHz threshold derived from the mean of 2 and 4 kHz thresholds when necessary. Air-bone gaps (ABGs) were determined from air conduction and bone conduction thresholds. Post-operative hearing gain was computed based on PTAs obtained preoperatively and post-operative examination.

Statistical analysis of the results was conducted using Student t-tests and chi-square tests, with significance set at $p<0.05$.

RESULTS AND DISCUSSIONS

In our study involving 178 patients, we noted notable differences in pre-and post-operative air conduction pure tone averages (AC PTAs) and air-bone gaps (ABGs). However, there was no significant variance observed in bone conduction pure tone averages (BC PTAs) when comparing pre-and post-operative data (refer to Table 1).

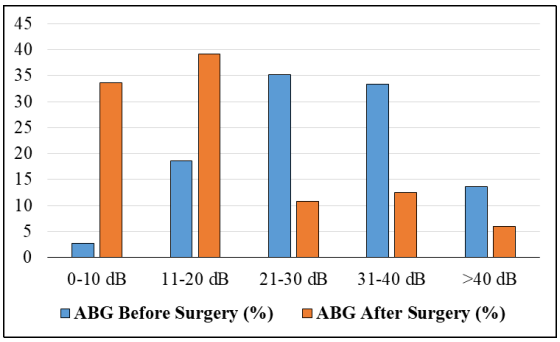

Fig. 1: Patients' pre-and post-operative ABGs (air-bone gaps)

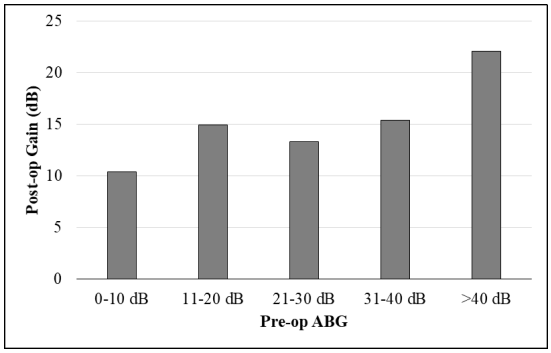

Fig. 2: Patients' post-operative gain compared to pre-operative ABG

(Fig. 1) illustrates the pre-and post-operative ABGs of the patients. Following surgery, there was an evident enhancement in the number of patients with ABGs of 0-10 dB and 11-20 dB, increasing from 2.7-33.61% and from 18.56-39.13%, respectively.

The correlation analysis of the mean gain with the ABG indicated that patients with pre-operative ABGs of 0-10 dB, 11-20 dB, 21-30 dB and 31-40 dB exhibited less improvement post-operatively compared to patients with pre-operative ABGs exceeding 40 dB (as depicted in Fig. 2).

Upon evaluation, post-surgery, significant enhancements were observed in air conduction PTAs for both TORP and PORP groups (refer to Table 2). Additionally, substantial ABG improvements were noted in patients undergoing ossicular chain reconstruction with autologous cartilage graft interposition, those with a remodeled incus and those with a synthetic prosthesis (refer to Table 3).

Despite the array of available procedures, the primary goals of cholesteatoma surgery remain consistent: to eliminate the disease and preserve optimal hearing function. The management of chronic otitis media with cholesteatoma has undergone significant evolution in recent times[7,8], transitioning from radical mastoidectomy to tympanoplasty with or without ossiculoplasty. For a considerable period, canal wall up tympanoplasty was the preferred approach. However, despite its superior hearing outcomes, recurrence rates appeared to be higher compared to canal wall down tympanoplasty, often necessitating multiple surgical interventions[2-5].

Hence, the preferred procedure for middle-ear cholesteatoma ideally involves canal wall down tympanoplasty[9-11], with a focus on optimizing hearing outcomes. While this procedure is commonly performed, there is limited documentation of actual hearing results in existing literature[12,13]. Ossiculoplasty within canal wall down tympanoplasty is not extensively discussed as a distinct topic and functional outcomes are often influenced by significant variability in surgical techniques and criteria for evaluating hearing results.

In our investigation, we analyzed the functional outcomes among patients with chronic otitis media accompanied by cholesteatoma who underwent canal wall down tympanoplasty with ossiculoplasty. Dhornhoffer[14] detailed a technique involving partial mastoid obliteration and reconstruction utilizing a tympanic ring with cartilage, aiming to deepen the middle-ear cleft, which yielded promising hearing outcomes. Similarly, Ikeda *et al*.[15] focused on posterior canal wall reconstruction to re-aerate the tympanic cavity.

Through ossiculoplasty, our aim was to enhance the proportion of patients achieving satisfactory hearing outcomes despite the open surgical approach. Our study revealed a notable decrease in the air-bone gap (ABG) during the post-operative period. Subsequent to surgery, a significant improvement was observed in the number of patients with ABGs ranging from 0-10 dB and 11-20 dB, respectively. Consequently, nearly two-thirds of our patients achieved closure of their ABG pure tone averages (PTAs) to 20 dB or less. Furthermore, substantial gains were noted particularly when the pre-operative ABG exceeded 40 dB. We deduce that a considerable proportion of patients experienced substantial hearing enhancement post-surgery, even among those with cholesteatoma graded as beyond stage one during surgery.

Our functional outcomes align closely with those reported by other researchers. Berenholz *et al*.[16] in a series of staged canal wall down tympanoplasty with ossiculoplasty procedures, documented an average postoperative air-bone gap (ABG) of 17.8 dB. Babighian[13] observed an average post-operative ABG of 25.4 dB following single-stage canal wall down tympanoplasty with ossiculoplasty for cholesteatoma, a result similar to that reported by Cook *et al*.[17] for the same procedure. However, comparisons with these findings should consider several factors. we presented functional results based on four frequency pure tone

Table 1: Pure tone audiometry results before and after surgery

Parameter	Before surgery	After surgery	p-value
AC-PTA	48.42±15.46	36.65±15.85	<0.05
BC-PTA	21.03±12.4	23.09±20.04	0.74
ABG	29.28±9.41	13.24±15.33	<0.05

Table 2: Hearing results according to type of prostheses used in surgery

Variable	Total ossicular replacement prosthesis			Partial ossicular replacement prosthesis		
	Before Surgery	After Surgery	p-value	Before Surgery	After Surgery	p-value
AC-PTA	48.28±10.90	44.91±16.97	<0.05	49.96±15.89	35.29±14.44	<0.05
BC-PTA	20.35±9.60	23.42±10.93	<0.05	23.33±12.69	22.40±13.53	<0.05
ABG	28.40±8.67	18.03±16.68	<0.05	27.33±9.55	14.69±15.28	<0.05

Table 3: Hearing results according to Remodeled Ossicles, Autologous Graft and Synthetic Prosthesis

	Remodeled Ossicles			Autologous Graft			Synthetic Prosthesis		
Variable	Before Surgery	After Surgery	p-value	Before	After Surgery	p-value Surgery	Before Surgery	After Surgery	p-value
AC-PTA	48.46±14.72	36.03±15.82	<0.05	48.28±15.29	34.43±12.07	<0.05	50.92±19.48	40.03±21.76	<0.05
BC-PTA	21.38±11.31	22.20±11.89	0.87	19.52±14.16	21.19±14.16	0.79	23.64±12.92	22.40±14.85	0.91
ABG	27.09±9.21	13.82±15.08	<0.05	26.75±9.16	12.25±15.39	<0.05	29.59±8.45	19.84±12.44	<0.05

averages (PTA) (0.5, 1, 2 and 4 kHz), we factored in the Carhart effect[18] to avoid overestimation of ABG closure and we employed a single-stage procedure which typically yields lower absolute gain compared to staged procedures.

The notable disparity in the patient numbers between our partial ossicular replacement prosthesis (PORP) and total ossicular replacement prosthesis (TORP) groups precluded an assessment of the impact of stapes integrity on surgical functional outcomes. Nonetheless, several authors[19,20] have concluded that the presence of the stapes superstructure does not significantly influence hearing gain, despite its expected contribution to the acoustic gain of the middle-ear mechanism, which may result in poorer performance of TORP compared to PORP due to reduced stability.

In recent years, there has been a rise in the use of synthetic prostheses in ossicular chain reconstruction. However, our analysis did not reveal significant differences in postoperative ABG improvement attributable to the materials used. Unfortunately, the unequal distribution of patients receiving autologous versus synthetic materials in our series precluded a statistically significant comparison.

CONCLUSION

Our findings indicate the potential for hearing improvement in canal wall down mastoidectomy utilizing cartilage placed above the prosthesis between stapes or stapes footplate. Failures observed were likely attributed to insufficient footplate-prosthesis contact or progressive fibrosis of the remaining middle-ear space. Despite this, the positive functional outcomes from our study underscore the importance of reconstructing the ossicular chain in canal wall down tympanoplasty procedures. Furthermore, our results advocate for additional clinical investigations to enhance the hearing outcomes associated with this surgical approach.

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