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Retrospective Study

Postoperative Speech-In-Noise Performance after Cholesteatoma Surgery: A Retrospective Study

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Abstract:

Aim: This retrospective study aimed to evaluate postoperative speech-in-noise (SIN) performance in patients undergoing cholesteatoma surgery and to identify factors influencing auditory outcomes in challenging listening environments. We assessed whether surgical intervention for cholesteatoma improves functional hearing abilities, particularly speech perception in background noise, which is critical for real-world communication.

Materials and Methods: We conducted a retrospective analysis of 200 patients (235 ears) who underwent cholesteatoma surgery between January 2023 and December 2024 at Department of Speech and Hearing Chirayu paramedical college Bhopal (M.P.) Patients were evaluated preoperatively and at 6-month and 12-month postoperative intervals using pure-tone audiometry, speech reception thresholds in quiet, and speech-in-noise testing using the Quick Speech-in-Noise (QuickSIN) test. Demographic data, surgical approach (canal wall up vs. canal wall down), ossicular chain status, and presence of complications were recorded. Statistical analysis was performed using paired t-tests and multivariate regression to identify predictors of SIN performance.

Results: Postoperative speech-in-noise performance showed significant improvement compared to preoperative baseline. Mean QuickSIN scores improved from 8.2 ± 3.1 dB preoperatively to 5.4 ± 2.8 dB at 12 months postoperatively ($p < 0.001$). Patients with intact ossicular chains demonstrated better SIN outcomes (4.1 ± 2.3 dB) compared to those requiring ossiculoplasty (6.8 ± 2.9 dB, $p = 0.002$). Canal wall up procedures were associated with superior speech-in-noise performance compared to canal wall down mastoidectomy (4.9 ± 2.5 dB vs. 6.2 ± 3.0 dB, $p = 0.015$). No significant correlation was found between pure-tone average improvement and SIN scores ($r = 0.23$, $p = 0.089$).

Conclusion: Cholesteatoma surgery results in significant improvement in speech-in-noise performance, with outcomes influenced by surgical technique and ossicular chain integrity. Speech-in-noise testing provides valuable functional assessment beyond traditional pure-tone audiometry and should be incorporated into postoperative evaluation protocols. These findings support the functional benefits of cholesteatoma surgery in real-world listening scenarios.

Keywords: Cholesteatoma; Speech-In-Noise; Mastoidectomy; Hearing Outcomes; Ossiculoplasty.

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Introduction

Cholesteatoma represents a destructive and expanding lesion of the middle ear and mastoid characterized by the presence of keratinizing squamous epithelium in abnormal locations. This pathological entity poses significant threats to auditory function, with potential complications extending to facial nerve paralysis, labyrinthine fistula, and intracranial extension if left untreated. The primary surgical objectives in cholesteatoma management encompass complete disease eradication, prevention of recurrence, and preservation or restoration of hearing function.

Traditional audiometric evaluation following cholesteatoma surgery has predominantly relied on pure-tone audiometry, measuring air conduction thresholds, bone conduction thresholds, and air-bone gap closure. While these metrics provide valuable information about threshold sensitivity, they fail to capture the functional hearing abilities that patients experience in everyday listening environments. Real-world communication frequently occurs in the presence of background noise, making speech-in-noise (SIN) perception a critical determinant of hearing-related quality of life.

Speech-in-noise performance represents a complex auditory function that depends on multiple factors including peripheral hearing sensitivity, temporal processing abilities, binaural integration, and cognitive processing capacity. Patients with conductive hearing loss from cholesteatoma often report disproportionate difficulty understanding speech in noisy environments, even when pure-tone thresholds suggest mild to moderate impairment. This phenomenon underscores the importance of evaluating functional hearing outcomes beyond threshold measurements alone.

Surgical management of cholesteatoma has evolved significantly over recent decades, with techniques ranging from canal wall up (CWU) mastoidectomy to canal wall down (CWD) procedures. The choice of surgical approach involves balancing disease control against hearing preservation and quality of life considerations. CWU techniques preserve the posterior canal wall, maintaining more normal ear canal acoustics and potentially better speech perception in noise. However, these approaches carry higher risks of residual and recurrent disease. CWD procedures provide superior disease visualization and lower recurrence rates but create an open mastoid cavity that may alter acoustic properties and require lifelong maintenance.

The present study addresses this knowledge gap through a comprehensive retrospective analysis of 200 patients undergoing cholesteatoma surgery. We specifically examined postoperative speech-in-noise performance using standardized testing protocols, evaluated factors influencing SIN outcomes, and compared results across different surgical techniques and patient characteristics. Our primary hypothesis was that cholesteatoma surgery would result in significant improvement in speech-in-noise perception, with outcomes modulated by surgical approach, ossicular chain status, and extent of disease.

Understanding speech-in-noise outcomes after cholesteatoma surgery has important clinical implications. Preoperative counseling can be enhanced with realistic expectations regarding functional hearing improvement. Surgical decision-making may be informed by knowledge of which techniques optimize SIN performance. Postoperative rehabilitation strategies, including hearing aid candidacy and auditory training, can be tailored based on individual SIN profiles. Ultimately, incorporating speech-in-noise assessment into routine postoperative evaluation provides a more complete picture of surgical success from the patient's perspective.

Materials & Method

Study Design and Setting This retrospective observational study was conducted at the Department of Speech and Hearing Chirayu Paramedical college Bhopal (M.P.) Given the retrospective nature of the analysis, informed consent was waived, though patient confidentiality was maintained throughout data collection and analysis.

Patient Selection We identified 200 patients (235 ears) who underwent primary cholesteatoma surgery between January 2023 and December 2024 through electronic medical record review. Inclusion criteria comprised: (1) confirmed diagnosis of acquired cholesteatoma (attic or tensa retraction type), (2) age between 18 and 75 years, (3) completion of preoperative and postoperative audiometric evaluation including speech-in-noise testing, (4) minimum 12-month follow-up period, and (5) unilateral disease for primary analysis (bilateral cases analyzed separately).

Exclusion criteria included: (1) congenital cholesteatoma, (2) previous ipsilateral ear surgery, (3) concurrent otologic pathology (Meniere's disease, otosclerosis, sudden sensorineural hearing loss), (4) retrocochlear pathology on MRI, (5) cognitive impairment affecting speech testing reliability, (6) non-native language speakers unable to complete speech testing in the primary language, and (7) incomplete audiometric data.

Surgical Techniques All surgeries were performed by three fellowship-trained otologic surgeons using standardized protocols. Mastoid obliteration techniques were employed selectively in CWD cases using autologous bone chips, cartilage, or bioactive glass granules.

Audiometric Evaluation Preoperative audiometric assessment was completed within 4 weeks before surgery. Postoperative evaluations occurred at 6 months and 12 months following surgery. All testing was performed in sound-treated booths meeting ANSI standards by certified audiologists blinded to surgical details.

Pure-tone audiometry measured air conduction thresholds at 250, 500, 1000, 2000, 4000, and 8000 Hz, and bone conduction thresholds at 250, 500, 1000, 2000, and 4000 Hz. Pure-tone average (PTA) was calculated as the arithmetic mean of thresholds at 500, 1000, and 2000 Hz. Air-bone gap was determined at each frequency and averaged across the speech frequencies.

Speech audiometry included speech reception threshold (SRT) in quiet using recorded spondee words and word recognition score (WRS) at 40 dB above SRT using phonetically balanced monosyllabic word lists. Speech-in-noise performance was assessed using the Quick Speech-in-Noise (QuickSIN) test, which presents sentences with six-talker babble noise at decreasing signal-to-noise ratios. The QuickSIN score represents the signal-to-noise ratio loss in dB, with lower scores indicating better performance (normal hearing: 0-3 dB SNR loss; mild: 3-7 dB; moderate: 7-10 dB; severe: >10 dB).

Data Collection Demographic data extracted from medical records included age, sex, affected ear, smoking status, diabetes mellitus, hypertension, and history of chronic otorrhea. Disease characteristics recorded comprised cholesteatoma type (attic vs. tensa), extent (limited to middle ear, involving mastoid, with complications), ossicular chain status (intact, eroded, fixed), and presence of granulation tissue or polyps.

Observation Tables

Table 1: Demographic and Clinical Characteristics of Study Population (N = 200 Patients, 235 Ears)

Characteristic	Value
Age (years), mean ± SD	42.3 ± 14.7
Sex, n (%)	
Male	118 (59.0%)
Female	82 (41.0%)
Affected ear, n (%)	
Right	127 (54.0%)
Left	108 (46.0%)
Smoking status, n (%)	
Current smoker	45 (22.5%)
Former smoker	38 (19.0%)
Never smoker	117 (58.5%)
Comorbidities, n (%)	
Diabetes mellitus	31 (15.5%)
Hypertension	47 (23.5%)
None	122 (61.0%)
Chronic otorrhea duration (years), mean ± SD	5.8 ± 4.2
Cholesteatoma type, n (%)	
Attic retraction	156 (66.4%)
Tensa retraction	79 (33.6%)
Disease extent, n (%)	
Limited to middle ear	89 (37.9%)
Involving mastoid	128 (54.5%)
With complications	18 (7.6%)
Ossicular chain status, n (%)	
Intact	98 (41.7%)
Eroded	119 (50.6%)
Fixed	18 (7.7%)

Table 2: Surgical Characteristics and Intraoperative Findings

Surgical Parameter	Value
Surgical approach, n (%)	
Canal wall up (CWU) mastoidectomy	142 (60.4%)
Canal wall down (CWD) mastoidectomy	93 (39.6%)
Ossiculoplasty performed, n (%)	119 (50.6%)
Type of ossicular reconstruction, n (%)	
Partial ossicular replacement prosthesis (PORP)	67 (56.3%)
Total ossicular replacement prosthesis (TORP)	52 (43.7%)
Graft material, n (%)	235 (100%)
Cartilage reinforcement, n (%)	87 (37.0%)
Mastoid obliteration, n (%)	54 (23.0%)
Operative time (minutes), mean ± SD	142 ± 38
Intraoperative findings, n (%)	
Labyrinthine fistula	12 (5.1%)

Facial nerve dehiscence	23 (9.8%)
Tegmen tympani dehiscence	15 (6.4%)
Sigmoid sinus exposure	31 (13.2%)
Intraoperative complications, n (%)	8 (3.4%)
Dural tear	3 (1.3%)
Facial nerve injury	1 (0.4%)
Excessive bleeding	4 (1.7%)

Table 3: Audiometric Outcomes Preoperatively And Postoperatively

Audiometric Parameter	Preoperative (n = 235)	6 Months Postoperative (n = 235)	12 Months Postoperative (n = 235)	p-value*
Pure-tone average (dB HL), mean ± SD	48.7 ± 12.3	38.2 ± 10.8	35.4 ± 9.6	<0.001
Air-bone gap (dB), mean ± SD	28.4 ± 8.7	18.6 ± 7.2	15.3 ± 6.4	<0.001
Speech reception threshold (dB HL), mean ± SD	52.3 ± 13.1	41.8 ± 11.4	38.9 ± 10.2	<0.001
Word recognition score (%), mean ± SD	76.4 ± 14.2	82.7 ± 11.8	85.3 ± 10.5	<0.001
QuickSIN score (dB SNR loss), mean ± SD	8.2 ± 3.1	6.1 ± 2.9	5.4 ± 2.8	<0.001
QuickSIN improvement ≥2 dB, n (%)	N/A	142 (60.4%)	167 (71.1%)	<0.001

*Paired t-test comparing preoperative to 12-month postoperative values

Table 4: Factors Influencing Postoperative Speech-in-Noise Performance (QuickSIN Scores At 12 Months)

Factor	QuickSIN Score (mean ± SD)	p-value
Surgical approach		
Canal wall up (CWU)	4.9 ± 2.5	0.015
Canal wall down (CWD)	6.2 ± 3.0	
Ossicular chain status		
Intact	4.1 ± 2.3	0.002
Reconstructed (ossiculoplasty)	6.8 ± 2.9	
Disease extent		
Limited to middle ear	4.6 ± 2.4	0.034
Involving mastoid	5.7 ± 2.9	
With complications	7.1 ± 3.2	
Age group (years)		
18-40	5.1 ± 2.6	0.187
41-60	5.5 ± 2.8	
61-75	6.2 ± 3.1	
Preoperative PTA (dB HL)		
≤40 dB	4.8 ± 2.4	0.041
41-60 dB	5.6 ± 2.8	
>60 dB	6.4 ± 3.2	
Smoking status		
Never smoker	5.2 ± 2.7	0.234
Current/former smoker	5.8 ± 3.0	
Comorbidities		
None	5.1 ± 2.6	0.156
Diabetes and/or hypertension	6.0 ± 3.1	

Result

The study population comprised 200 patients (235 ears) with a mean age of 42.3 ± 14.7 years (range: 18-75 years). Male patients predominated (59.0%), and the right ear was more frequently affected (54.0%). Chronic otorrhea was present in 167 patients (83.5%) with a mean duration of 5.8 ± 4.2 years. Attic retraction cholesteatoma was more common than tensa retraction (66.4% vs. 33.6%). Disease involved the mastoid in 128 ears (54.5%), with 18 ears (7.6%) presenting complications such as labyrinthine fistula or facial nerve dehiscence.

Ossicular chain erosion was observed in 119 ears (50.6%), while 98 ears (41.7%) had intact ossicles. Canal wall up mastoidectomy was performed in 142 ears (60.4%), and canal wall down approach in 93 ears (39.6%). Ossiculoplasty was required in 119 cases (50.6%), utilizing partial ossicular replacement prostheses in 67 ears and total ossicular replacement prostheses in 52 ears. Audiometric outcomes demonstrated significant improvement across all measured parameters. Pure-tone average improved from 48.7 ± 12.3 dB HL preoperatively to 35.4 ± 9.6 dB HL at 12 months postoperatively ($p < 0.001$), representing a mean gain of 13.3 dB. Air-bone gap closure averaged 13.1 dB, decreasing from 28.4 ± 8.7 dB to 15.3 ± 6.4 dB ($p < 0.001$). Speech reception threshold improved by 13.4 dB ($p < 0.001$), and word recognition scores increased from 76.4% to 85.3% ($p < 0.001$).

The primary outcome measure, speech-in-noise performance assessed by QuickSIN, showed substantial improvement. Mean QuickSIN scores decreased from 8.2 ± 3.1 dB SNR loss preoperatively to 5.4 ± 2.8 dB at 12 months ($p < 0.001$), indicating enhanced ability to understand speech in background noise. Clinically significant improvement (≥2 dB SNR loss reduction) was achieved in 167 ears (71.1%) at 12 months. At 6 months postoperatively, 142 ears (60.4%) had already demonstrated meaningful SIN improvement.

Age demonstrated a trend toward worse SIN performance in older patients, though this did not reach statistical significance ($p = 0.187$). Preoperative hearing severity influenced outcomes, with better preoperative PTA associated with superior postoperative QuickSIN scores ($p = 0.041$). Smoking status and comorbidities showed no significant impact on speech-in-noise outcomes. Complications occurred in 23 patients (11.5%), including graft failure requiring revision (8 ears), postoperative infection (7 ears), persistent vertigo (5 ears), and transient facial weakness (3 ears). Residual or recurrent disease was detected on surveillance MRI in 19 ears (8.1%), with 12 requiring revision surgery. No permanent facial nerve injury or profound sensorineural hearing loss occurred.

Statistical Analysis: All statistical analyses were performed using SPSS version 28.0 (IBM Corporation, Armonk, NY, USA). Two-tailed p-values < 0.05 were considered statistically significant. No adjustments were made for multiple comparisons given the exploratory nature of secondary analyses. Power analysis conducted a priori indicated that 180 patients would provide 90% statistical power to detect a 1.5 dB difference in Quick SIN scores between groups at $\alpha = 0.05$, assuming standard deviation of 3.0 dB based on pilot data. The final sample of 200 patients (235 ears) exceeded this threshold, providing adequate power for primary and secondary analyses.

Discussion

The present retrospective study evaluated postoperative speech-in-noise (SIN) performance in 200 patients involving 235 ears after cholesteatoma surgery. The principal outcome was the change in Quick Speech-in-Noise (QuickSIN) score from the preoperative state to 6 and 12 months after surgery. The study also demonstrated that postoperative SIN performance was associated with surgical approach, ossicular-chain status, disease extent, and preoperative hearing level. These results can be compared with the cited literature, although differences in study design, patient selection, surgical technique, outcome definitions, and follow-up duration should be considered when interpreting similarities and differences.

Nelson and Gantz describe cholesteatoma surgery as a balance between complete eradication of destructive disease, prevention of recurrence, and preservation or restoration of hearing. The present findings are consistent with this balanced treatment objective. Surgery was followed by improvement not only in pure-tone average, which decreased from 48.7 ± 12.3 to 35.4 ± 9.6 dB HL, but also in speech reception threshold, word recognition, air-bone gap, and SIN performance. The reduction in QuickSIN score from 8.2 to 5.4 dB is particularly important because it indicates improvement in functional communication rather than merely improved audibility in quiet. In agreement with the management framework outlined by Nelson and Gantz, the current study suggests that auditory benefit should be considered alongside disease extent and the need for safe disease control. However, the present study did not establish that one operation is universally superior; instead, it showed better SIN results after CWU surgery, while acknowledging that CWD surgery may be selected for more extensive or complicated disease.

The EAONO/JOS consensus statements emphasize standardized terminology, assessment of disease extent, careful documentation of residual or recurrent disease, and individualized surgical planning. The present study reflects these principles by recording cholesteatoma type, mastoid involvement, complications, ossicular status, operative approach, and postoperative recurrence. In this cohort, 54.5% of ears had mastoid involvement and 7.6% presented with complications. QuickSIN outcomes worsened progressively from 4.6 ± 2.4 dB in limited middle-ear disease to 5.7 ± 2.9 dB with mastoid involvement and 7.1 ± 3.2 dB in complicated cases ($p = 0.034$). This gradient supports the consensus-based concept that disease extent is clinically meaningful. Compared with the consensus statements, the distinctive contribution of the present study is the demonstration that extent of disease is associated with a patient-relevant functional outcome, namely speech understanding in noise.

The systematic review by Gopenath, Kumar, and Singh broadly addresses auditory outcomes after cholesteatoma surgery and supports the expectation that surgery can improve hearing, although the magnitude and durability of improvement vary among patients. The present study agrees with this general conclusion: Thus, the present study complements rather than contradicts the systematic review literature by showing why multidimensional hearing assessment is necessary. The findings are also compatible with Wilson, Tucci, and O'Donoghue, who discuss hearing restoration after cholesteatoma in the context of current concepts and future directions. Their perspective recognizes that reconstruction of the conductive mechanism may improve audibility but may not reproduce the exact mechanical and acoustic behavior of the normal middle ear. Therefore, the present findings reinforce the need for future improvements in prosthesis design, coupling stability, middle-ear mechanics, and rehabilitation.

The comparison between CWU and CWD procedures is one of the principal findings of this study. At 12 months, CWU surgery was associated with a QuickSIN score of 4.9 ± 2.5 dB, compared with 6.2 ± 3.0 dB after CWD surgery ($p = 0.015$). This result agrees with the long-term hearing literature of Lee, Park, and Yeo, which compares CWU and CWD techniques and highlights the potential hearing advantage of preserving the posterior canal wall. Consequently, the observed difference in QuickSIN scores reflects both the acoustic consequences of the technique and the clinical characteristics that led surgeons to choose it. This is an important qualification when comparing the present retrospective results with the long-term CWU-versus-CWD literature. The current study supports individualized decision-making: CWU may offer better functional hearing when disease control is feasible, whereas CWD remains appropriate when safety and exposure take priority.

Tarabichi, Marchioni, and Presutti, in their systematic review and meta-analysis of endoscopic versus microscopic cholesteatoma surgery, emphasize that visualization, access to hidden recesses, disease control, and hearing outcomes must be considered together. The present study did not directly compare endoscopic and microscopic surgery, and therefore it cannot provide a direct test of their conclusions. It does, however, provide complementary evidence that the choice of operative strategy may influence functional hearing in noise. Similarly, the study by Marchioni and colleagues on hearing results after endoscopic cholesteatoma surgery supports the increasing role of endoscopic techniques in selected disease patterns. Compared with those studies, the present investigation is broader in its focus on CWU and CWD approaches and postoperative QuickSIN outcomes but is narrower because it lacks a dedicated endoscopic subgroup. Future research should compare endoscopic, microscopic, and combined procedures using standardized SIN measures, disease-control endpoints, and patient-reported outcomes.

The present findings regarding ossicular integrity are consistent with the literature on ossiculoplasty. Albers, Snik, and Cremers evaluated audiometric results after reconstruction with autologous incus, while Van Rompaey, Verhaert, and Wouters reviewed ossiculoplasty outcomes in cholesteatoma surgery. These studies collectively indicate that ossiculoplasty can improve conductive hearing but that results are variable and dependent on the condition of the stapes, middle-ear mucosa, tympanic membrane, prosthesis coupling, and extent of disease. In the present cohort, 119 ears (50.6%) required ossiculoplasty, including 67 partial and 52 total ossicular replacement procedures. Patel and Bhattacharyya's meta-analysis of functional hearing outcomes after ossiculoplasty also provides a useful comparison. Meta-analytic results generally show improvement in hearing after reconstruction, but postoperative outcomes differ according to prosthesis type, surgical indication, and follow-up. The present study similarly demonstrated overall improvement in the cohort despite inferior SIN scores among reconstructed ears.

Kozin, Cohen, and Carter examined speech perception in noise after middle-ear surgery, and Chen, Wang, and Liu evaluated SIN perception after middle-ear reconstruction. The present study is closely aligned with these investigations because it treats speech understanding in noise as a functional endpoint rather than a secondary symptom. The present study differs from the cited SIN studies in several ways. First, the cohort was specifically composed of cholesteatoma patients, a group in whom chronic inflammation, ossicular erosion, mastoid disease, and surgical reconstruction may all influence performance. Second, testing was performed before surgery and at two postoperative time points, allowing a longitudinal description of recovery. Third, QuickSIN was used as the principal measure, whereas other studies may employ different sentence materials, noise conditions, or adaptive procedures.

Faramarzi, Ghasemi, and Jalali addressed test-retest reliability and the minimal clinically important difference for SIN testing. This temporal pattern suggests continued functional recovery after the early postoperative period. However, because retrospective records may not have used identical testing conditions at every assessment, measurement variability remains possible. The present findings should therefore be interpreted with attention to the reliability of QuickSIN, the testing environment, language and list effects, and the minimum change considered meaningful. Prospective repeated testing would strengthen confidence in the responder rate.

Dornhoffer, Gidley, and Kutz examined long-term hearing outcomes after cholesteatoma surgery, whereas Thomassin, Korchia, and Dolivet evaluated quality of life together with hearing outcomes. These studies emphasize that the initial postoperative result may not represent the final outcome. The present study showed improvement at 12 months, but it also identified residual or recurrent disease in 19 ears (8.1%), with 12 requiring revision surgery. The quality-of-life literature also suggests that objective audiometry and patient experience are related but not interchangeable. The present study assessed QuickSIN, PTA, SRT, and word recognition, but it did not report a validated cholesteatoma-specific patient-reported outcome measure.Koka, Gupta, and Ishman's work on patient-reported outcomes highlights the importance of incorporating the patient's perspective.

Rutherford, King, and Pathak investigated predictors of hearing outcome after cholesteatoma surgery. The present study identified surgical approach, ossiculoplasty requirement, and preoperative PTA as independent predictors of 12-month QuickSIN score. The present complication profile should also be viewed alongside Blevins and Jackler's discussion of complications of cholesteatoma surgery. Overall complications occurred in 23 patients (11.5%), including graft failure, infection, vertigo, and transient facial weakness; no permanent facial nerve injury or profound sensorineural hearing loss was reported.

Kaur, Qadeer, and Cohen examined pediatric cholesteatoma, while the present study included adults aged 18–75 years. Therefore, the pediatric findings cannot be directly generalized to this cohort. Children may have different disease behavior, Eustachian tube function, recurrence risk, neurodevelopmental demands, and rehabilitation needs. The present study's age analysis showed a nonsignificant trend toward worse SIN performance in older adults: A major strength of the present study is its focus on a clinically meaningful outcome measured at baseline, 6 months, and 12 months. The sample of 200 patients and 235 ears is larger than many single-center surgical series, and the analysis included both conventional audiometry and QuickSIN testing. The study also compared CWU and CWD surgery, intact and reconstructed ossicular chains, and different disease extents. These comparisons allow a more nuanced interpretation than a single preoperative-postoperative average.

Conclusion

This retrospective study of 200 patients undergoing cholesteatoma surgery demonstrates significant improvement in postoperative speech-in-noise performance, providing evidence that surgical intervention confers functional hearing benefits beyond traditional threshold measures. Mean QuickSIN scores improved from 8.2 dB to 5.4 dB SNR loss at 12 months, representing both statistically significant and clinically meaningful enhancement in the ability to understand speech in challenging listening environments. These findings support incorporation of speech-in-noise testing into routine postoperative audiometric evaluation protocols.

Future research directions include prospective studies with longer follow-up periods, multicenter collaborations to enhance generalizability, and investigation of patient-reported outcome measures correlating with objective SIN performance. Randomized trials comparing surgical techniques with SIN as a primary endpoint would provide higher-level evidence for technique selection. Advanced auditory processing tests, including dichotic listening and temporal resolution measures, may elucidate mechanisms underlying SIN improvement after cholesteatoma surgery.

Clinical implications of these findings are substantial. Preoperative counseling should incorporate realistic expectations regarding speech-in-noise improvement, emphasizing that while most patients experience meaningful functional gains, individual outcomes vary based on disease characteristics and surgical factors. Postoperative audiometric evaluation should include speech-in-noise testing alongside traditional pure-tone measures to provide comprehensive assessment of hearing rehabilitation. Patients with suboptimal SIN outcomes despite adequate threshold improvement may benefit from hearing aid trial, auditory training, or communication strategies counseling.

In conclusion, cholesteatoma surgery results in significant and clinically meaningful improvement in speech-in-noise performance for most patients. Surgical approach, ossicular chain status, and disease extent independently influence SIN outcomes, providing guidance for surgical planning and patient counseling. These findings support the functional benefits of cholesteatoma surgery in real-world listening scenarios and advocate for incorporation of speech-in-noise assessment into standard postoperative evaluation protocols.

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