

Stapes Surgery in Patients with Otosclerosis Aged 65 Years or Older: Postoperative Hearing Outcomes. A 20-Year Experience

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ABSTRACT

Introduction: otosclerosis is an osteodystrophy of the otic capsule that affects the middle and inner ear, with an approximate prevalence of 1% in the general population, a female predominance, and usual onset between 30 and 40 years of age. It primarily manifests as conductive or mixed hearing loss. Surgical treatment is the treatment of choice in patients with adequate cochlear reserve, with success rates, defined as an air-bone gap (ABG) closure and bone conduction (BC) change ≤ 10 dB, ranging from 67% to 94%. However, as the disease is progressive, sensorineural hearing loss may persist or progress, requiring subsequent auditory rehabilitation.

Objective: to evaluate hearing outcomes in patients aged ≥ 65 years who underwent stapes surgery.

Materials and methods: observational, retrospective, descriptive study. Sixty-three patients (72 ears) diagnosed with otosclerosis who underwent surgery between January 2004 and December 2024 were included. Demographic variables and pre- and postoperative audiological parameters were analyzed, including ABG, bone conduction (BC), and pure-tone average (PTA) at frequencies of 0.5, 1, 2, and 4 kHz.

Results: of the patients, 58.7% were women (female-to-male ratio, 1.4:1). Mixed hearing loss was present in 98.6% of patients. Bilateral involvement was observed in 52.3% of cases. ABG closure ≤ 10 dB was achieved in 85.4% of ears, and a BC change ≤ 10 dB was achieved in 85%. The PTA showed a mean improvement of -6.25 dB for air conduction and -6.25 dB for bone conduction. Mean follow-up was 7.9 years. Postoperatively, 22% of patients required hearing aids. Minor complications occurred in 9.52% of cases.

Conclusion: stapes surgery in patients aged over 65 years is an effective and safe procedure, with high rates of audiological success and a low incidence of complications, constituting a valid therapeutic option for this age group.

Keywords: stapedotomy, stapes surgery, functional hearing loss, hearing results, hearing loss.

Cirugía estapediovestibular en pacientes con otoesclerosis de 65 años o más: resultados auditivos posoperatorios. Experiencia de 20 años

RESUMEN

Introducción: la otosclerosis es una osteodistrofia de la cápsula ótica que afecta el oído medio e interno, con una prevalencia aproximada del 1% en la población general, predominio femenino y presentación habitual entre los 30 y 40 años. Se manifiesta principalmente como hipoacusia conductiva o mixta. El tratamiento quirúrgico es de elección en pacientes con adecuada reserva coclear, con tasas de éxito,

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definidas como cierre del gap aéreo-óseo (ABG) y variación de conducción ósea (BC) ≤ 10 dB, que oscilan entre 67 y 94%. Sin embargo, al tratarse de una enfermedad progresiva, puede persistir o progresar la hipoacusia neurosensorial, requiriendo rehabilitación auditiva posterior.

Objetivo: evaluar los resultados auditivos en pacientes ≥ 65 años sometidos a cirugía estapedial.

Materiales y métodos: estudio observacional, retrospectivo y descriptivo. Se incluyeron 63 pacientes (72 oídos) con diagnóstico de otosclerosis, intervenidos entre enero de 2004 y diciembre de 2024. Se analizaron variables demográficas y parámetros audiológicos preoperatorios y posoperatorios, incluyendo ABG, conducción ósea (BC) y promedio tonal puro (PTA) en frecuencias de 0,5, 1, 2 y 4 kHz.

Resultados: el 58,7% de los pacientes fueron mujeres (relación 1,4:1). El 98,6% presentó hipoacusia mixta. La afección fue bilateral en el 52,3% de los casos. Se logró un cierre de ABG ≤ 10 dB en el 85,4% de los oídos y una variación de BC ≤ 10 dB en el 85%. El PTA mostró una mejoría promedio de -6,25 dB en vía aérea y -6,25 dB en vía ósea. El seguimiento medio fue de 7,9 años. El 22% de los pacientes requirió audífonos en el posoperatorio. Se registraron complicaciones menores en el 9,52% de los casos.

Conclusión: La cirugía estapedial en pacientes mayores de 65 años es un procedimiento eficaz y seguro, con altas tasas de éxito audiológico y baja incidencia de complicaciones, constituyendo una opción terapéutica válida en este grupo etario.

Palabras clave: otosclerosis, estapedotomía, cirugía del estribo, pérdida auditiva funcional, hipoacusia, resultados auditivos.

INTRODUCTION

Otosclerosis is an osteodystrophy of the otic capsule characterized by an initial phase of bone resorption followed by new bone formation.¹ Historically, Valsalva first described the disease in 1735; Toynbee identified stapes ankylosis as a cause of deafness in 1860; von Troeltsch introduced the term “sclerosis” in 1881; Politzer coined the term “otosclerosis” in 1894; and Siebenmann proposed “otospongiosis” for the active phase of the disease in 1912.^{2,3}

Lesions typically originate in the fissula *ante fenestram* or involve the cochlea, resulting in fenestral and retrofenestral forms.⁴ Its etiopathogenesis is multifactorial and remains uncertain, with a clinical prevalence of approximately 1%, a female predominance, and autosomal dominant inheritance with incomplete penetrance.^{1,4,5} Diagnosis is based on clinical and audiologic findings. The disease primarily presents as conductive hearing loss with a significant air-bone gap and may involve a sensorineural component in advanced stages.⁶⁻⁸ The Symons and Fanning CT classification allows assessment of disease extent.^{9,10}

Treatment is individualized. Although medical treatment options are available to stabilize disease progression, stapes surgery is the treatment of choice for patients with significant conductive hearing loss and adequate cochlear reserve, while hearing rehabilitation is reserved for selected cases.^{1,10,11}

Although stapes surgery has shown excellent audiologic outcomes in the general population, evidence regarding its outcomes in older adults remains limited, particularly with long-term follow-up. In this context, the

present study evaluates postoperative hearing outcomes in patients aged 65 years or older who underwent stapes surgery at our center.

Primary Objective

To evaluate long-term hearing outcomes in patients with otosclerosis aged 65 years or older who underwent stapes surgery at Hospital Italiano de Buenos Aires between January 2004 and December 2024.

Secondary Objectives

1. To determine the hospital prevalence of patients aged ≥ 65 years who underwent stapes surgery at any time during January 2004 to December 2024.

2. To describe the demographic characteristics and clinical presentation based on audiometric findings, as well as the grade of otosclerosis according to the Symons and Fanning classification on temporal bone CT.

3. To determine postoperative audiologic outcomes in terms of improvement in the bone-conduction (BC) threshold and reduction in the air-bone gap (ABG).

4. To determine the mean postoperative follow-up time and characterize patients who required amplification devices after surgery.

MATERIALS AND METHODS

We conducted a retrospective, observational, descriptive study.

We reviewed the electronic medical records of patients aged 65 years or older who underwent stapes surgery for otosclerosis at Hospital Italiano between January 2004 and December 2024.

We created an Excel spreadsheet to collect data on the following variables: sex, current age and age at surgery, unilateral or bilateral otosclerosis, type of hearing loss documented by preoperative audiometry (mixed, conductive, or sensorineural), type of surgery performed, and preservation of the chorda tympani. Based on preoperative and postoperative audiometry, we evaluated bone conduction (BC), air conduction (AC), and the air-bone gap (ABG) individually at frequencies of 500, 1000, 2000, and 4000 Hz. We also calculated the pure-tone average (PTA), defined as the mean hearing threshold at selected frequencies, to summarize a patient's hearing level. We used the following formula recommended by the American Academy of Otolaryngology–Head and Neck Surgery (AAO-HNS) for the evaluation of otosclerosis:

$$PTA = (500 \text{ Hz} + 1000 \text{ Hz} + 2000 \text{ Hz} + 4000 \text{ Hz}) / 4^{12,13}$$

The grade of otosclerosis was determined according to the Symons and Fanning classification on multislice CT of the temporal bones. We also recorded postoperative complications, follow-up duration, and the need for amplification devices after surgery.

Postoperative audiologic outcomes were assessed using two independent endpoints: (1) closure of the air-bone gap (ABG) to ≤ 10 dB HL and (2) preservation of bone conduction (BC), defined as a postoperative change of ≤ 10 dB HL relative to

preoperative audiometry at each frequency analyzed. The two parameters were analyzed independently.

The study protocol was approved by the Research Ethics and Protocol Committee of Hospital Italiano (No. 7148). The study was also registered with the Buenos Aires Electronic Registry Platform for Health Research (PRIISA), under No. 13372.

Population

Patients with a clinical, audiologic, and/or CT diagnosis of otosclerosis who underwent stapes surgery at Hospital Italiano between January 2004 and December 2024 and were aged 65 years or older as of January 1, 2025.

Inclusion Criteria

Patients diagnosed with otosclerosis and treated at Hospital Italiano who underwent stapes surgery at the institution between January 2004 and December 2024. Patients were also required to have audiometry and speech audiometry results available in their electronic medical records and postoperative follow-up of more than 1 year.

EXCLUSION CRITERIA

We excluded patients who were younger than 65 years as of January 1, 2025, as well as those without complementary audiologic studies (audiometry and speech audiometry) in their medical records or with insufficient postoperative follow-up of less than 1 year (Fig. 1).

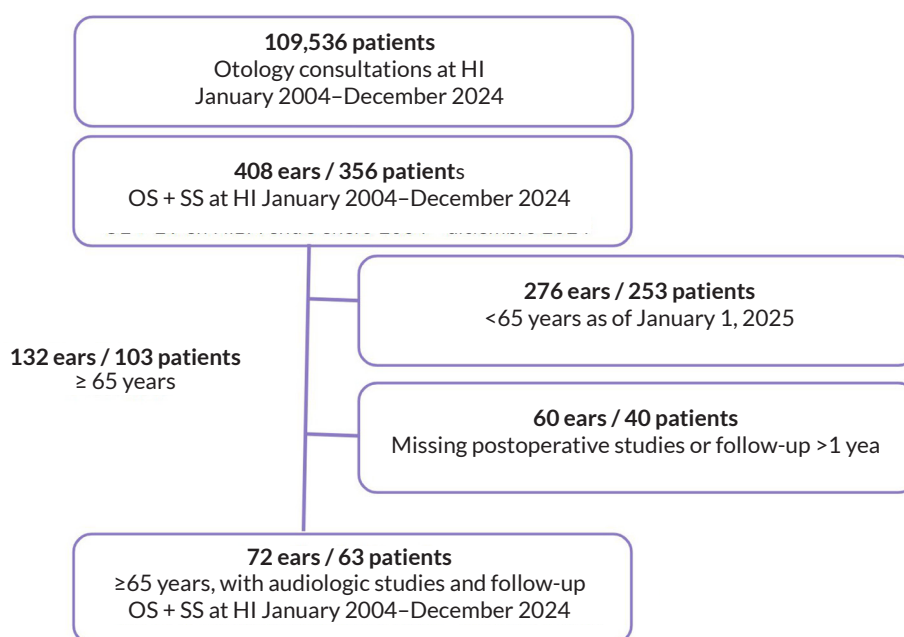


Figure 1. Study population. Inclusion and exclusion criteria. OE: otosclerosis. EV: stapedial-vestibular surgery. HI: Hospital Italiano (Buenos Aires, Argentina)

RESULTS

Between January 2004 and December 2024, 109,536 consultations were recorded in the Otolaryngology Section of Hospital Italiano. The hospital prevalence of otosclerosis among patients who underwent stapedial-vestibular surgery was 0.33% (365 cases/109,536 patients seen). The proportion of stapedial-vestibular (EV) surgeries performed in patients aged ≥65 years was 28% (103 cases/365 patients who underwent EV surgery) at the same center during the same period.

This retrospective, descriptive, observational study included 63 patients (72 ears) aged over 65 years who underwent stapes surgery for otosclerosis at our center between January 2004 and December 2024. Twenty-six men and 37 women underwent surgery. Women accounted for 58.7% of the sample, with a female-to-male ratio of 1.4:1. Of these, 41 patients (65.1%) underwent surgery before the age of 65 years, with a mean age of 58.7 years (range, 47–64), whereas 22 patients (34.9%) underwent surgery at age ≥65 years, with a mean age of 68.4 years (range, 65–89).

Stapedotomy was performed in 55 (83%) cases and stapedectomy in 17 (23.6%). The chorda tympani was preserved during surgery in 31 (58.3%) patients. No differences were identified among the prostheses used.

Surgical candidates were selected from among patients with suspected otosclerosis based on clinical assessment, audiometric studies, and temporal bone computed tomography (CT), when available. Of the 72 ears, 71 (98.6%) had mixed hearing loss and 1 (1.4%) had conductive hearing loss.

Of the 63 patients, 33 (52.3%) had bilateral otosclerosis and 30 (47.6%) had unilateral disease. Among the latter, 13 underwent surgery on the right ear and 17 on the left ear. Of the patients with bilateral disease, only 9 underwent surgery on both ears, while the remainder underwent surgery on only one ear.

Temporal bone CT scans were available in the medical records of 46 ears (63.8%). The Symons and Fanning classification was applied considering the findings in both temporal bones (both ears) of each patient. Of these, 6 patients (8.3%) were classified as grade 0, 34 (47.2%) as grade I, 3 (4.2%) as grade II, and 3 (4.2%) as grade III. Preoperative CT studies were not found in the medical records of 26 ears (36.1%).

Postoperative audiologic outcomes were analyzed using two independent parameters: ABG closure to ≤10 dB HL and preservation of bone conduction, defined as a change of ≤10 dB HL relative to preoperative audiometry.

At 500 Hz, the mean preoperative ABG was 40 dB [20–70 dB], with ABG closure to ≤10 dB HL achieved in 59.7% (43 surgeries). At 1000 Hz, the mean preoperative ABG was 35 dB [10–65 dB], and ABG closure was achieved in 87.5% (63 surgeries). At 2000 Hz, the preoperative ABG was 20 dB [0–50 dB], and ABG closure was achieved in 98.6% (71 surgeries).

At 4000 Hz, the mean preoperative ABG was 15 dB [0–40 dB], and complete ABG closure was achieved in 95.8% (69 surgeries).

The mean preoperative ABG across the four frequencies studied was 26.25 dB, compared with 5 dB postoperatively. The mean rate of ABG closure to ≤10 dB across the same frequencies was 85.4% (Tables 1 and 2).

Mean preoperative bone-conduction (BC) thresholds were 15 dB [0–40 dB] at 500 Hz, 30 dB [0–50 dB] at 1000 Hz, 40 dB [15–70 dB] at 2000 Hz, and 50 dB [15–80 dB] at 4000 Hz. A BC change of ≤10 dB HL was observed at all frequencies: in 63.8% (46 surgeries) at 500 Hz, 87.5% (63 surgeries) at 1000 Hz, and 94.4% (68 surgeries) at both 2000 and 4000 Hz. Overall, BC was preserved within 10 dB in 85% of cases across all frequencies (Fig. 2, Table 3).

The pure-tone average (PTA) was calculated according to the American Academy of Otolaryngology–Head and Neck Surgery (AAO-HNS) recommendations,^{13,14} comparing preoperative and postoperative results. The change in patients’ PTA, calculated as the difference between postoperative and preoperative PTA, had a mean of –6.25 dB (mean improvement).

Preoperative air-conduction (AC) thresholds were assessed by frequency. The mean preoperative PTA was 62.5 dB [60–70 dB], compared with a mean postoperative PTA of 36.25 dB [25–50 dB].

Table 1. Preoperative and postoperative air-bone gap (ABG) values by frequency

Frequency (Hz)	Preoperative ABG	Postoperative ABG
500 Hz	40 dB [20–70 dB]	10 dB [0–40 dB]
1000 Hz	30 dB [10–65 dB]	10 dB [0–40 dB]
2000 Hz	20 dB [0–50 dB]	5 dB [0–20 dB]
4000 Hz	15 dB [0–40 dB]	0 dB [0–40 dB]
Mean ABG	26.25 dB	5 dB

Hz: Hertz. dB: decibels

Table 2. Mean air-bone gap (ABG; difference between air conduction [AC] and bone conduction [BC]) ≤10 dB by frequency (Hz)

Frequency (Hz)	ABG ≤10 (dB)
500 Hz	59.7% (43 cirugías)
1000 Hz	87.5% (63 cirugías)
2000 Hz	98.6% (71 cirugías)
4000 Hz	95.8% (69 cirugías)
Mean ABG ≤ 10 (dB)	85.40%

Hz: Hertz. dB: decibels

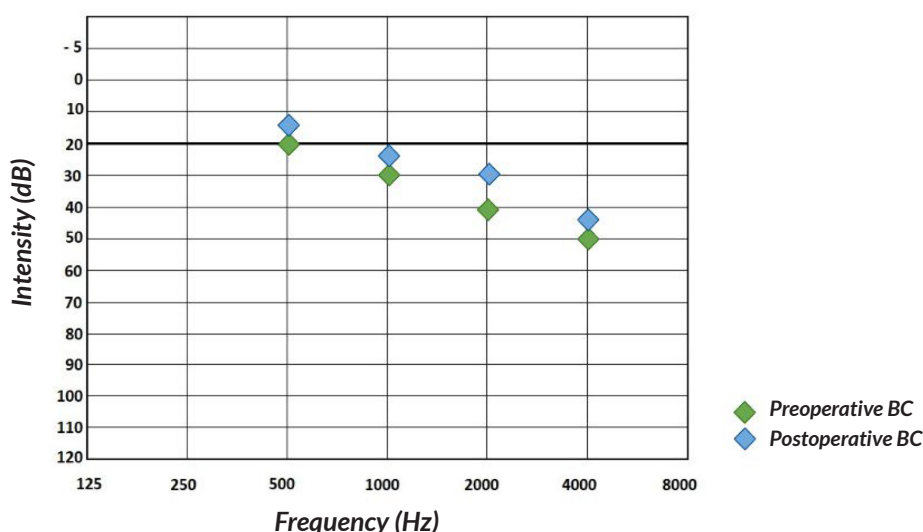


Figure 2. Weighted mean preoperative and postoperative bone-conduction (BC) thresholds. (Hz, hertz; dB, decibels).

Table 3. Mean percentage of cases with a bone-conduction (BC) change ≤ 10 dB HL, by frequency.

Frecuencia (Hz)	BC ≥ 10 (dB)
500 Hz	63,8% (46 cirugías)
1000 Hz	87,5% (63 cirugías)
2000 Hz	94,4% (68 cirugías)
4000 Hz	94,4% (68 cirugías)
Mean BC ≤ 10 (dB)	85%

Hz: Hertz. dB: decibels

The difference between postoperative and preoperative PTA values (Δ PTA) was -26.25 dB, representing a considerable improvement with ABG closure.

Mean postoperative follow-up was 7.9 years. After surgery, 14 patients (22%) required hearing aids, at a mean age of 71.7 years. The mean interval between surgery and hearing-aid use was 3.9 years. All of these patients had postoperative BC ≤ 10 dB and ABG ≤ 10 dB. The bone-conduction PTA in the ear contralateral to surgery was 32.5 dB.

Of these patients, 64.3% (9 patients) underwent surgery at age ≥ 65 years. Overall, 93% (13 patients) required hearing aids in both ears, whereas only one patient used a hearing aid unilaterally in the operated ear. However, 5 patients required a hearing aid in the contralateral ear without otosclerosis because of an audiometric pattern consistent with presbycusis.

In addition, 2 patients with bilateral otosclerosis were already using hearing aids in both ears before surgery, and 1 patient was using a hearing aid in the contralateral ear before surgery because of presbycusis, with no signs of osteodystrophy of the temporal bone.

In this subgroup analysis, 2 of the 3 patients in the series with grade III osteodystrophy according to the Symons and Fanning classification required hearing aids. However, no linear correlation was found between more severe radiologic grades of otosclerosis and postoperative hearing outcomes or the need for hearing-assistive devices.

Postoperative complications occurred in 9.52% of patients (6 patients). One patient had a residual tympanic membrane perforation requiring subsequent tympanoplasty, and another developed a granuloma that was managed on an outpatient basis. One patient experienced prosthesis extrusion and underwent revision surgery with placement of a longer prosthesis (4.75 mm). In addition, 2 patients experienced worsening of preexisting tinnitus, which resolved with medical treatment and psychotherapy. Another patient developed Ramsay Hunt syndrome 1 month after surgery, with no auditory sequelae.

DISCUSSION

Otosclerosis has an estimated clinical prevalence of 0.4% in populations of European ancestry, whereas histopathologic studies have shown involvement in up to 2.5% of temporal bones.¹⁵ The proportion of patients undergoing stapes surgery ranges from 35% to 54% in population-based studies, whereas patients older than 65 years account for 3% to 16% of cases in surgical series.¹⁶ In our series, this age group accounted for 28.9% of the surgeries performed.

The disease is more common in women, with a female-to-male ratio of approximately 2:1 in previous series.^{7,15}

In our sample, women accounted for 58.7%, with a female-to-male ratio of 1.4:1. Bilateral involvement is common;¹⁷ in our series, 58.3% of cases were bilateral and 41.6% unilateral.

Previous studies have reported preoperative hearing loss as conductive or mixed, with variations depending on the

population studied.^{17,18} In our cohort, 98.6% of patients had mixed hearing loss and 1.4% had conductive hearing loss.

The Symons and Fanning CT classification has shown high interobserver and intraobserver agreement ($\kappa \approx 0.92$) and is useful for assessing disease extent before surgery.²⁰ In our series, temporal bone CT was available in 63.8% of cases; however, no correlation was observed between more advanced CT grades, postoperative hearing outcomes, and the need for hearing aids.

However, despite the high rate of hearing improvement, the audiologic parameters evaluated in this study—namely, ABG closure to ≤ 10 dB HL and preservation of BC—vary across studies in the literature. Based on these parameters, Salvador et al. reported successful stapes surgery in 67.2% of patients.¹⁶ These findings are consistent with those of other authors, who have reported rates of ABG closure to within 10 dB ranging from 62% to 94%.^{21,22}

Vincent et al. evaluated 93 cases of stapes surgery and found that 59% of patients achieved a postoperative ABG ≤ 10 dB and 57% achieved a BC gain ≥ 20 dB. They also identified a larger ABG as a positive prognostic factor.²³ In the present study, ABG closure to ≤ 10 dB was achieved in 85.4% of cases, with a mean preoperative ABG of 26.3 dB. A BC change of ≤ 10 dB HL was observed in 85% of cases at the same frequencies.

Carhart described decreased bone conduction at 2000 Hz (the Carhart notch) as a characteristic finding in otosclerosis, attributable to increased impedance at the oval window. After stapes surgery, improvement in bone conduction, particularly correction of the Carhart notch, is considered an indicator of favorable postoperative hearing outcomes.²⁴ In our series, the weighted mean BC threshold at 2000 Hz was 40 dB preoperatively and 30 dB postoperatively, with a BC change of ≤ 10 dB in 94.4% of cases (68 surgeries) and correction of the Carhart notch, consistent with findings reported in the literature.

Recent studies have reported significant improvements in BC thresholds and ABG closure across all age groups ($p < 0.05$). BC thresholds improved significantly in patients aged < 50 years. Linear regression showed a modest negative correlation between age and BC improvement ($R^2 = 0.18$, $p = 0.006$). Despite smaller gains in older patients, no significant differences were found between younger and older groups in changes in ABG or BC ($p > 0.05$). The findings showed that stapes surgery is a suitable treatment even for older adults with mixed hearing loss, provided that the ABG is limited to 20–30 dB.²⁵ In the present study, among patients who underwent surgery after age 65 years, the mean change in bone-conduction PTA (Δ PTA) was -6.25 dB, indicating an improvement. This represents a considerable hearing improvement comparable to that reported in younger patients in the literature.

Retrospective clinical studies have shown that stapes surgery in patients older than 65 years is as safe and effective as in younger patients. In one analysis, audiologic outcomes and complication rates were comparable between 42 patients aged > 60 years and 275

patients younger than 60 years.²⁶ In another series of 473 primary procedures, which included 16 patients older than 65 years, all achieved ABG reduction to < 20 dB. ABG closure to < 10 dB was achieved in 87% at 1 month and maintained in 82% over a mean follow-up of 20 months.²⁷ These findings support stapes surgery as a valid treatment option for older adults, with clinical outcomes comparable in terms of efficacy and safety.

Regarding treatment, in selected cases, hearing aids alone may serve as a noninvasive treatment option for otosclerosis. However, they often provide insufficient benefit for speech discrimination. Therefore, combined treatment with surgery and hearing aids has been recognized as the most appropriate approach for patients with mixed hearing loss and postoperative BC thresholds > 30 dB HL.²⁸

In the study by Wardenga et al.,²⁷ 44.9% of patients did not require hearing aids after surgery. Among patients who did require hearing aids postoperatively, a power hearing aid met the audiologic criteria at all four frequencies in 81.6% of cases.²⁸ When necessary, these patients could be fitted with a lower-power hearing aid, which was considered a successful outcome.²⁵ In comparison, in our series, 22% (14 patients) required hearing aids after surgery, after a mean interval of 3.9 years. All of these patients had postoperative BC and ABG values ≤ 10 dB.

In a study by Ishai et al., the mean long-term sensorineural hearing loss attributable to otosclerosis was significantly greater at each frequency than that attributable to aging alone. Approximately one-third of patients with otosclerosis showed clinically significant progression of the sensorineural component of hearing loss, with mean BC deterioration exceeding expected age-related changes, ranging from 10 to 15 dB at the frequencies evaluated in this subgroup.⁸ Patients who required hearing aids in our series had a mean bone-conduction PTA of 32.5 dB in the ear contralateral to surgery.

Recent series have reported that serious complications are uncommon, with profound and severe sensorineural hearing loss occurring in 0.2% and 3.2% of cases, respectively, and a revision surgery rate of 4.5%. Postoperative vertigo occurs in 18% of patients and persists in 6%, while tinnitus and taste disturbances occur in 3.6% and 4.7%, respectively. Less frequent complications, such as facial paresis or perilymphatic fistula, occur in approximately 1% of cases.²⁹

In our series, the complication rate was 9.52% (6 patients), including residual tympanic membrane perforation, granuloma, prosthesis extrusion requiring revision surgery, worsening of preexisting tinnitus, and one case of Ramsay Hunt syndrome. Nevertheless, all patients maintained favorable audiologic outcomes.

Limitations

This study has several limitations. Its retrospective, descriptive design may introduce biases inherent in medical record review and limit control over potential confounding variables. In addition, including only patients selected for surgery may introduce selection bias.

Finally, the absence of a comparison group of younger patients precludes direct comparisons between age groups; therefore, the findings should be interpreted in the context of a descriptive case series.

CONCLUSION

Stapes surgery in patients older than 65 years was associated with improved audiologic outcomes, as evidenced by air-bone gap closure and improvement in the Carhart notch, including at 2000 Hz. The need for hearing aids during follow-up was also low, with only 22% of patients requiring amplification after surgery. These findings support stapes surgery as a treatment option for patients older than 65 years who meet the criteria for surgical treatment.

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