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OBJECTIVES: The object of this study was to review patients who underwent stapes surgery during a 15-year period, together with an evaluation of techniques, results, and complications.

PATIENTS AND METHODS: Otosclerosis surgery was performed in 483 adult patients (305 females, 178 males; mean age 46.3 years; range 24 to 74 years) between 1988 and 2002. The disease was bilateral in 292 patients (60.5%) and unilateral in 191 patients (39.5%). Operations were unilateral in 451 patients, and bilateral in 32 patients, and included small fenestra stapedotomy with a perforation of 0.8 mm (442 ears, 85.8%), partial stapedectomy with removal of the posterior half of the footplate (30 ears, 5.8%), and total stapedectomy (43 ears, 8.4%). A Teflon prosthesis, 0.6 mm in diameter and 4-4.5 mm length, was used nearly in all the cases. In cases of stapedectomy, a perichondrial graft was placed over the oval window. Preoperative and postoperative hearing levels (frequencies 500, 1000, 2000, and 3000 Hz) and air- and bone-conduction thresholds (frequencies 250, 500, 1000, 2000, and 4000 Hz) were measured. Postoperative closure of the air-bone gap was evaluated in four groups: grade A (gap≤10 dB HL), grade B (11-20 dB HL), grade C (21-30 dB HL), and grade D (>30 dB HL). The results were evaluated in accordance with the guidelines of the Committee on Hearing and Equilibrium-1995. Of 515 operations, 380 were evaluative (73.8%) with respect to outcome. The mean follow-up period was 68 months (range 3 to 180 months).

RESULTS: Of 380 evaluative operations, 307 ears (80.8%) showed complete recovery with a postoperative air-bone gap less than 10 dB (grade A), whereas 10 ears (2.6%) showed no improvement in hearing thresholds and in the closure of the air-bone gap. Together with partial recoveries (grade B and C), the overall improvement in hearing thresholds was 97.3%. The mean preoperative and postoperative air-conduction hearing thresholds at frequencies of 500, 1000, 2000, and 3000 Hz were 56.3±14.5 dB HL and 28.3±9.7 dB HL, respectively. The mean gain for air conduction at the same frequencies was 25.3±11.7 dB HL. Of 10 ears in which no hearing recovery was observed, two ears rapidly developed sensorineural hearing loss. Revision surgery was performed in six of the remaining ears and resulted in complete response. Of these, air-bone gap closure was achieved in three ears, while one ear developed sensorineural hearing loss a few days after revision surgery. The most common complications encountered intraoperatively, and in the immediate and late postoperative periods were section of the chorda tympani (n=130, 25.2%), transient facial nerve paralysis (n=13, 2.5%), and sensorineural hearing loss (n=2, 0.4%), respectively.

CONCLUSION: Our results show that stapes surgery yields very good functional results, with complete or partial closure of the air-bone gap in the great majority of cases, and with very low rates of postoperative complications.
Otosclerosis is a dystrophic disorder of the labyrinthine capsule, with characteristic localization. Its most typical clinical manifestation is hearing loss due to progressive fixation of the stapes. The prevalence of clinical otosclerosis is 0.3-0.4% among whites\[1\] and there is a 2:1 female preponderance in the general population.\[2\]

In 40-54% of cases, otosclerosis has a hereditary basis,\[3,4\] and manifests characteristics of an autosomal dominant disease with incomplete penetrance (25-40%).\[5,6\] The clinical expressiveness of the gene may be conditioned by biochemical or hormonal factors.\[4\] Maurizi et al.\[7\] could not locate receptor sites for calcitonin in otosclerotic bone cell cultures, but found alterations in calcium metabolism. This discovery was further confirmed by Lim.\[8\] According to the autoimmune theory, the disorder is likely to stem from the production of autoantibodies to certain types of collagen, particularly type II, which is present in the enchondral layer and in residual embryonic cartilage of the auditory capsule.\[9\] More recent studies have addressed the possible role of measles virus in initiating the otosclerotic process.\[10-14\]

Treatment of otosclerosis dates back to the late nineteenth century, with numerous attempts for surgical remedy. Finally, in 1958, Shea\[15\] proposed the so-called stapedectomy, which included the removal of the stapes under an operation microscope, closure of the oval window with a thin slice of connective tissue, and implantation of a prosthesis from the incus to the oval window. Since then, many modifications of stapedectomy have been developed, all of which adhered to the principles of Shea, involving the closure of the oval window and the restoration of ossicular continuity.

One of these modifications is stapedotomy, which is based on the principle of restoring sound transmission by creating a partial opening in the stapes footplate. In this technique, manipulation of the stapes footplate is restricted to the small area of fenestration, reducing potential risks for any injury to the membranous labyrinth within the vestibule.\[10\] The size of the new fenestra can be from 0.3 to 0.8 mm, with the hearing results being comparable. In addition, differences both between the types of prostheses and between the techniques used to create the fenestra are slight. Many surgeons use a microdrill or perforator to fenestrate the footplate. Perkins,\[17\] introduced the use of laser to vaporize the stapes without instrumentation, which has then become popular.\[18,19\]

The object of this study was to review patients who underwent stapes surgery during a 15-year period (1988 to 2002), together with an evaluation of techniques, results, and complications, and to draw a comparison with the relevant literature reports.

**MATERIALS AND METHODS**

Otosclerosis surgery was performed in 483 adult patients (305 females, 178 males; mean age 46.3 years; range 24 to 74 years) between 1988 and 2002 by the same surgeon. Otosclerosis was bilateral in 292 patients (60.5%) and unilateral in 191 patients (39.5%). Preoperatively, all the patients underwent liminar pure tone audiometry, speech audiometry, tympanometry, and vestibular examinations.

Unilateral operation was performed in 451 patients, while 32 patients underwent surgery in both ears, making up a total of 515 operations. The operations were assessed in three categories according to the type of stapes manipulation: small fenestra stapedotomy resulting in a perforation of 0.8 mm (442 ears, 85.8%); partial stapedectomy with removal of the posterior half of the footplate (30 ears, 5.8%); and total stapedectomy with complete removal of the footplate (43 ears, 8.4%).\[20\]

A Teflon prosthesis with a diameter of 0.6 mm and a length of 4-4.5 mm was applied nearly in all the cases, and a 0.8 mm piston in some. A small amount of blood was left around the prosthesis to create a seal. In cases of stapedectomy, a perichondrial graft was placed over the oval window.

Preoperative and postoperative hearing levels (frequencies 500, 1000, 2000, and 3000 Hz) and air- and bone-conduction thresholds (frequencies 250, 500, 1000, 2000, and 4000 Hz) were measured. Postoperative closure of the air-bone gap was evaluated in four groups: grade A (gap≤10 dB HL), grade B (11-20 dB HL), grade C (21-30 dB HL), and grade D (>30 dB HL).

The results were evaluated in accordance with the guidelines recommended by the Committee on Hearing and Equilibrium of the American Academy of Otology (1995).\[21\]
Of 515 operations, 380 were evaluative (73.8%) with respect to outcome. The mean follow-up period was 68 months (range 3 to 180 months).

**RESULTS**

Of 380 evaluative operations, 307 ears (80.8%) showed complete recovery with a postoperative air-bone gap less than 10 dB (grade A), whereas 10 ears (2.6%) showed no improvement in hearing thresholds and in the closure of the air-bone gap (Table 1).

The mean preoperative and postoperative air-conduction hearing thresholds at frequencies of 500, 1000, 2000, and 3000 Hz were 56.3±14.5 dB HL and 28.3±9.7 dB HL, respectively. The mean gain for air conduction at the same frequencies was 25.3±11.7 dB HL. The mean preoperative and postoperative air- and bone-conduction thresholds measured at frequencies of 500, 1000, 2000 and 4000 Hz are tabulated in Table 2.

Of 10 ears in which no hearing recovery was observed, two ears rapidly developed sensorineural hearing loss. Revision surgery which was performed in six of the remaining eight ears resulted in complete response. Of these, air-bone gap closure was achieved in three ears, while one ear developed sensorineural hearing loss a few days after revision surgery.

Complications encountered intraoperatively, and in the immediate and late postoperative periods are shown in Table 3.

**DISCUSSION**

This study examines a series of 515 operations performed by the same surgeon for otosclerosis over a 15-year period. The analysis of the results reveals the indubitable effectiveness of the operations in providing major improvements in air-conduction hearing levels of the majority of patients. Indeed, the rate of air-bone gap of less than 10 dB HL (grade A) was 80.8% in 380 evaluative operations.

Together with partial recoveries (grade B and C), the overall improvement in hearing thresholds accounted for 97.3%.

The success rates reported in the literature following surgery for otosclerosis are tabulated in Table 4.[22-31] The variability in the improvement rates of hearing thresholds ranging from 78% to 96% can be attributed to the use of varying criteria to evaluate the results, different surgical techniques, and, last but not least, the variable lengths of postoperative follow-up periods.[32]

The rates of intraoperative and postoperative complications were similar to those reported in other studies. Our rate for sensorineural hearing loss (0.4%) was comparable to those reported as 0.4% and 3%. [27,33] Compared to reported rates of 08%, [31] 1%, [27] and 1.9%, [34] perforation of the tympanic membrane occurred in 0.7% in our study. The rate of postoperative vertigo (1.0%) was also similar to 0.7% reported by Glasscock et al.[27] The occurrence a floating footplate in nine ears (1.8%) had no effect whatsoever on the final results. This complication showed a significant decrease upon inverting the order of surgical applications, i.e. placing the prosthesis before removing the superstructure of the stapes.

With regard to the type of the operation, the common opinion in the literature is that small fenestra stapedotomy furnishes similar results to those of stapedectomy, but with fewer complications. In 1978, Smyth and Hassard[24] reported better performance rates with small fenestra operations (diameter 0.4 mm) in a study of 800 ears. In 1981, McGee[23]...
pointed out an inversely proportional relationship between the size of the fenestra and auditory improvement. In 1982, Fisch\[35\] compared the results of stapedectomies and stapedotomies, indicating that the latter yielded better gap closure at 4000 Hz. Other studies also reported better air-bone gap closure following stapedotomy operations, particularly at higher frequencies and with lower complication rates.\[36-38\] Moreover, Persson et al.\[38\] found that long-term results of stapedectomy involved a higher rate of deterioration in hearing thresholds. Spandow et al.\[39\] demonstrated better improvement in air-conduction thresholds with small fenestra stapedotomy in the frequency range of 4-6 kHz. Finally, Gjuric\[40\] pointed out that it would be safer to create a small opening in the visible part of the footplate in patients with an overhanging facial nerve, so that removal of the prosthesis could be easier and less hazardous for the inner ear, if revision surgery might be necessary.

However, there are some authors that favor the use of partial or total stapedectomies over small fenestra operations. Rizer and Lippy\[41\] reported that partial or total stapedectomies yielded better results, compared with small fenestra operations, in the range of frequencies involved in language comprehension. Ferrario et al.\[42\] compared the merits of stapedectomy and small fenestra stapedotomy: while the former resulted in better improvement in air conduction, the latter was found more reliable in controlling the postoperative course of bone conduction for acute tones, probably due to the fact that it involved a more limited vestibular exposure and lower potential risks to the labyrinth; hence, far more fewer problems of dizziness in the postoperative clinical course.

In our study, we could not draw statistical interpretations concerning the effectiveness of the techniques employed because of the small size of stapedectomy operations. Yet, taking into account both our results and the growing number of reports in favor of small fenestra operations, we are of the opinion that stapedotomy offers more advantageous

### Table 3. Intraoperative, immediate postoperative and late postoperative complications

<table>
<thead>
<tr>
<th>Complication</th>
<th>No. of ears</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intraoperative complications/ anatomical variations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Section of the chorda tympani</td>
<td>130</td>
<td>25.2</td>
</tr>
<tr>
<td>Presence of the overhanging facial nerve</td>
<td>15</td>
<td>2.9</td>
</tr>
<tr>
<td>Presence of “biscuit” footplate</td>
<td>13</td>
<td>2.5</td>
</tr>
<tr>
<td>Floating footplate</td>
<td>9</td>
<td>1.8</td>
</tr>
<tr>
<td>Tympanic membrane perforation</td>
<td>4</td>
<td>0.8</td>
</tr>
<tr>
<td>Local hemorrhage</td>
<td>4</td>
<td>0.8</td>
</tr>
<tr>
<td>Fixed malleus</td>
<td>2</td>
<td>0.4</td>
</tr>
<tr>
<td>Perilymph gusher</td>
<td>1</td>
<td>0.2</td>
</tr>
<tr>
<td>Immediate postoperative</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acute vertigo</td>
<td>5</td>
<td>1.0</td>
</tr>
<tr>
<td>Transient facial nerve paralysis</td>
<td>13</td>
<td>2.5</td>
</tr>
<tr>
<td>Late postoperative</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensorineural hearing loss</td>
<td>2</td>
<td>0.4</td>
</tr>
<tr>
<td>Alteration in gustatory sensitivity</td>
<td>1</td>
<td>0.2</td>
</tr>
</tbody>
</table>

### Table 4. Literature data on case studies concerning the improvement in the closure of the air-bone gap

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>No. of ears</th>
<th>Duration</th>
<th>Success rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moon (1968)[22]</td>
<td>460</td>
<td>–</td>
<td>96.0</td>
</tr>
<tr>
<td>House (1967)[23]</td>
<td>140</td>
<td>4 mo</td>
<td>92.0</td>
</tr>
<tr>
<td>Smyth and Hassard (1978)[24]</td>
<td>584</td>
<td>4 mo</td>
<td>94.0</td>
</tr>
<tr>
<td>McGee (1981)[25]</td>
<td>255</td>
<td>6 mo</td>
<td>91.1</td>
</tr>
<tr>
<td>Moller (1992)[26]</td>
<td>215</td>
<td>3-6 mo</td>
<td>95.0</td>
</tr>
<tr>
<td>Glasscock et al. (1995)[27]</td>
<td>600</td>
<td>1-243 mo</td>
<td>91.3</td>
</tr>
<tr>
<td>Sedwick et al. (1997)[28]</td>
<td>550</td>
<td>4 mo</td>
<td>78.2</td>
</tr>
<tr>
<td>Frias et al. (2000)[29]</td>
<td>183</td>
<td>1 yr</td>
<td>79.0</td>
</tr>
<tr>
<td>Kos et al. (2001)[30]</td>
<td>604</td>
<td>1-21 yr</td>
<td>79.0</td>
</tr>
<tr>
<td>Agrawal and Parnes (2002)[31]</td>
<td>112</td>
<td>2.5 mo</td>
<td>85.7</td>
</tr>
<tr>
<td>Simoncelli et al. (2005)</td>
<td>380</td>
<td>3-180 mo</td>
<td>80.8</td>
</tr>
</tbody>
</table>
results in terms of inner ear performance, particularly in clinically advanced forms of otosclerosis.\(^{18,37,43}\)

Stapes surgery is generally performed under local anesthesia and can be considered for elderly patients or those presenting with an advanced impairment of the cochlear reserve.\(^{42,44,45}\)

The data provided by this study and by relevant literature reports clearly indicate that, in experienced hands, stapes surgery yields very good functional results, with complete or partial closure of the conductive gap in the great majority of cases, and with extremely low rates of intraoperative and postoperative complications. Moreover, improvement achieved surgically does not exclude the use of hearing aids that may be required to promote communication and socialization needs of the patient.

REFERENCES


25. McGee TM. Comparison of small fenestra and total