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Original Study

Simultaneous Cochlear Implantation After Translabyrinthine Vestibular Schwannoma Resection: A Report of 41 Cases

AQ1 *Mario Sanna, *Enrico Piccirillo, *Caterina Kihlgren, *Gloria Cagliero, *Mariapaola Guidi, and †‡Essam Saleh

AQ2 *Gruppo Otologico, Piacenza-Roma, Italy; †Otolaryngology, Alex. University, Egypt; and ‡Otology KAMC, Makka, Saudi Arabia

Objective: To study the auditory outcome of simultaneous translabyrinthine vestibular schwannoma (VS) resection and cochlear implantation (CI) after successful cochlear nerve preservation.

Study Design: A retrospective case series and patient questionnaire.

Setting: Quaternary referral center for skull base pathologies.

Patients: Patients with small (<2 cm) sporadic or neurofibromatosis 2 related tumors were included in this study.

Intervention: Vestibular schwannoma resection + simultasimultaneous cochlear implantation.

Main Outcome Measure: Audiological performance postimplantation and perceived patients' benefits.

Results: Forty-one patients were included. Thirty-three were sporadic VS and eight were neurofibromatosis 2. Auditory perception postimplantation was achieved in 33 patients (80.5%). At the last follow-up, 20 patients (48.8%) were users and 21 (51.2%) were nonusers. In the users' group, and after 1 year of implant activation, vowel identification was 75.3%, disyllabic word recognition 54%, sentence recognition 60.7%, and common phrase comprehension 61%, whereas in the nonusers' group and after 1 year of implant activation, vowel identification was 22.9%, disyllabic word recognition 14.8%, sentence recognition 15.3%, and common phrase comprehension 14%. Sixteen users were classified into 10 high performers, three intermediate performers, and three poor performers. In the user' group, the mean postimplantation pure tone average was 63.4 dB and the mean speech discrimination score was 63.7%.

Conclusions: Simultaneous CI and VS resection is a viable option with many patients achieving auditory perception and nearly half the patients are CI users at long follow-up.

Key Words: Choclear implant—Internal auditory canal—Pontocerebellar angle—Vestibular schwannoma.

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Vestibular schwannoma (VS) is a benign tumor of the Schwann cell that arises from the inferior or rarely from the superior vestibular nerve (1). It can be sporadic or bilateral as part of neurofibromatosis 2 (NF2). Current management of VS includes the conservative follow-up with serial imaging, stereotactic radiotherapy, and surgery (2).

Most patients with sporadic VS experience a decline in hearing in the involved ear despite undergoing observation, radiation treatment, or surgery. Nearly 80% of patients with VS are present with hearing loss (3). Preservation of serviceable hearing is a difficult task with all treatment modalities (4). In particular, patients undergoing hearing-preservation surgery often develop significant subjective hearing deficits and tinnitus postoperatively (5,6).

Patients with sporadic VS with contralateral normal hearing have the risk of losing binaural hearing with a resultant marked impact in communication skills owing to impaired sound localization and decreased speech understanding in noise. They experience significant disabilities in many situations, particularly when is necessary to communicate in competing background noise. The traditional rehabilitation of single-sided deafness (SSD) comprises hearing systems with routing of acoustic signals from the deaf ear to the normal-hearing ear, such as hearing aids with contralateral routing of signals or bone-conduction devices. These hearing systems overcome the head shadow but do not reliably improve sound localization (7,8). Studies have shown that only 25% to 40% of patients with SSD chose implantable bone-conduction device or hearing aids with contralateral routing of signals after a short trial period (5,9).

In contrast, cochlear implantation proved effective in improving speech perception and sound localization and

AQ3 Address correspondence and reprint requests to Enrico Piccirillo, AQ4 Gruppo Otologico, Piacenza-Roma, Italy; E-mail: enricopiccirillo@gruppootologico.it

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is the only currently available method that can restore true binaural hearing in SSD patients, thus leading to significant improvement in the quality of hearing and quality of life (10).

For patients with NF2 and bilateral VS, bilateral deafness might be inevitable, with limited hearing rehabilitation options available (11–13).

The aim of the present study was to evaluate the functional results of all patients in our center who had translabyrinthine removal of VS with simultaneous cochlear implantation (CI) insertion for auditory rehabilitation.

MATERIALS AND METHODS

The study protocol was approved by the ethics committee of our center. The study included 41 patients diagnosed with VS and operated with the enlarged translabyrinthine approach (ETLA) with gross tumor resection and simultaneous cochlear implantation. The ETLA entails wide exposure of at least 1 cm of the retrosigmoid and middle fossa dura providing wider access than the classic translabyrinthine approach. All patients had undergone the operation at our center in the period from November 2010 to April 2019. Thirty-three patients had sporadic tumors, whereas the remaining eight had NF2. Gadolinium-enhanced magnetic resonance imaging (MRI) was performed in all cases. Patients with a tumor extent greater than 1 cm in the cerebellopontine angle or with cochlear invasion were excluded. Detailed informed consent was obtained from all patients. Preoperative audiograms and speech discrimination score (SDS) calculations were performed in all cases with calculation of the postimplantation pure tone average (PTA) at frequencies of 500; 1,000; 2,000; and 4,000 Hz. All surgeries were performed by the senior author (MS). A senior author (MS) performed all operations of tumor removal with the enlarged translabyrinthine approach. After gross tumor removal, the anatomical integrity of the cochlear nerve was carefully assessed. The stapedial reflex and intraoperative electrically evoked compound action potential were performed after cochlear implantation. Intraoperative electrophysiologic tests were performed using the Nikolet® Viking Quest® System. The implants used were Med-El® (Concerto and Synchrony models) in 25 cases and Oticon® (Neuro ZCLA + Neuro 2 models) in 16 cases. In all cases, PTA and SDS were measured 1 year postoperatively. Assessments were made in a soundproof room, using free field with the CI switched on. The patient was seated nearly 1 m from the speaker placed at 0° azimuth. SDS was tested using a list of 10 disyllabic words. The contralateral ear was masked using a headphone utilizing 40-dB suprathreshold hearing. Masking was performed using narrowband noise when testing for PTA and white noise when testing for SDS. Postoperative auditory performances were also assessed in the auditory-only condition in both closed (vowel identification) and open (disyllabic word recognition, sentence recognition, and comprehension of familiar phrases) sets with a monitored live voice through the sound field at a level of 70 dB SPL. The Bocca and Pellegrini sentence list was utilized. Patients were tested in the free field condition. Contralateral hearing was masked with white noise according to the patient's hearing threshold. Auditory performance was expressed as percentage of correct words or sentences repeated by the patient. Based on CI use after at least 1 year postoperatively, patients were divided into groups of users and nonusers. Using the highest percent score reported on open-set speech recognition without visual cues, individual subject performances were categorized as high (67–100%), intermediate (34–66%), or low performance (1–33%) (14). In addition, all patients underwent audiological evaluation at the time of implant activation and 3, 6, and 12 months after activation. Users were also asked to respond to the speech, spatial, and qualities of hearing scale (SSQ) questionnaire and the hearing handicap questionnaire (HHQ) after at least 12 months after activation (15). In the SQQ, answers were given on a scale from 0 to 10 where 0 indicates minimal hearing and 10 the maximum hearing benefit. The HHQ comprised 12 items that addressed two topics: social limitation and emotional distress. Responses were scored using five-point scale (almost always, often, sometimes, rarely, never) (Appendix 1, http://links.lww.com/MAO/B291).

Statistical Analysis

Preoperative versus postoperative and ipsilateral versus contralateral hearing comparisons were performed using Student's *t* test. For nonparametric variables, Fisher's exact test was utilized. Statistical analyses were performed with IBM© SPSS© version 22.

RESULTS

We proposed cochlear implantation to 84 patients VS for whom surgery had been planned and among them 51 patients consented. A total of 10 patients were excluded; eight because the tumor infiltrated the cochlear nerve as assessed by the surgeon, and the remaining two because the VS extended into the cochlea. Finally, cochlear implantation was performed for 41 patients, including 19 men and 22 women. Their age ranged from 26 to 74 years with a mean of 49.9 ± 11.2 years. The mean tumor size was 9.4 ± 5.2 mm. Thirty-three patients had sporadic unilateral VS (15 left and 18 right), and the remaining eight patients had NF2 with bilateral tumors. The main symptoms were ipsilateral hearing loss in 36 patients, 16 of whom also had contralateral hearing loss (PTA $\geq$ 25 dB). Ten patients complained of dizziness, and eight patients complained of tinnitus. Five patients had instability. One patient had Usher syndrome. All operations were performed with the ETLA for complete tumor removal.

The mean ipsilateral PTA was 61.2 ± 28 dB preoperatively, and 75.83 ± 25 dB at 1 year postoperatively. The mean ipsilateral SDS was $58.3\% \pm 44\%$ preoperative, and $45.3\% \pm 41\%$ at 1 year postoperatively. Both differences were statistically significant ($p < 0.05$). There was no correlation between the preoperative and postoperative SDS ($p < 0.05$). There was also no correlation between tumor size and postoperative SDS ($p < 0.05$).

At the approximately 1-year follow-up, 20 patients were users (48.8%), whereas 21 (51.2%) were nonusers. Four nonusers became users within 2 years with a good auditory outcome and improved quality of life. Among nonusers, eight (19.5%) patients had no auditory stimulation, three of whom were explanted (one because of Usher syndrome and another had facial nerve stimulation). The mean age of users was 49.2 ± 13.7 years while

TABLE 1. *Comparison between the preoperative and postoperative pure tone average and speech discrimination score in the user and nonuser group*

	Preop Pathologic side		Postop Pathologic Side (Free Field with CI and Contralateral Masking)		Contralateral Side	
	PTA	SDS	PTA	SDS	PTA	SDS
Users	52.1 ± 29 dB	66.0 ± 42%	63.4 ± 13 dB	63.7 ± 35%	26.0 ± 10 dB	99.0 ± 3%
Nonusers	70.6 ± 25 dB	50.9 ± 45%	94.8 ± 23 dB[a]	16.9 ± 33%[a]	35.9 ± 25 dB	86 ± 29%
All patients	61.2 ± 28 dB	58.3 ± 44%	75.8 ± 25 dB	45.3 ± 41%	31.1 ± 19 dB	92.5 ± 21%

CI indicates cochlear implantation; PTA, postimplantation pure tone average; SDS, speech discrimination score.
[a]Eight patients who had no auditory stimulation with their implants were not included.

that of nonusers was 50.5 ± 8.6 years. The difference was not statistically significant. The tumor size in the user group ranged from 3 to 20 mm with a mean of 9.8 ± 4.8 mm while that in the nonuser group ranged from 3.5 to 20 mm with a mean of 9.1 ± 5.7 mm. The difference was not statistically significant.

Contralateral hearing loss (PTA ≥ 25 dB) was present in seven cases of the users and nine cases of the nonusers. One patient from the nonusers had contralateral profound hearing loss that was managed with cochlear implantation elsewhere. Comparing the contralateral PTA between user and nonuser groups showed no statistically significant difference ($p < 0.01$).

Comparing the postoperative free-field PTA and SDS (CI-activated) with the preoperative PTA and SDS, respectively, the user group showed no statistically significant differences (with a postoperative PTA of 63.4 ± 13 dB vs. a preoperative PTA of 52.1 ± 29 dB, and a postoperative SDS of 63.7 ± 35% vs. a preoperative SDS of 66.0 ± 42%), but the nonuser group showed a statistically significant worsening of hearing with a higher postoperative PTA (94.8 ± 23 dB vs. 70.6 ± 25 dB) and a lower preoperative SDS (16.9 ± 33%* vs. 50.9 ± 45%) ($p < 0.01$; Table 1). Comparing the preoperative ipsilateral PTA and SDS between the user and nonuser groups, the nonusers showed a statistically significant lower hearing (higher PTA and lower SDS; $p < 0.01$; Table 1). Severe to profound ipsilateral sensorineural hearing loss was found in three users and 10 nonusers, showing a statistically significant difference ($p < 0.01$).

In the user group, vowel identification was 44% at implant activation and 75.3% after 12 months; disyllabic word recognition was 29.2% at activation and 54% after 12 months; sentence recognition was 30.9% at activation and 60.7% at 12 months; and common phrase comprehension was 27.5% at activation and 61% after 12 months. In the nonuser group, vowel identification was 5% at implant activation and 22.9% after 12 months; disyllabic word recognition was 2.6% at activation and 14.8% after 12 months; sentence recognition was 2.9% at activation and 15.3% after 12 months; and common phrase comprehension was 0% at activation and 14% after 12 months (Fig. 1).

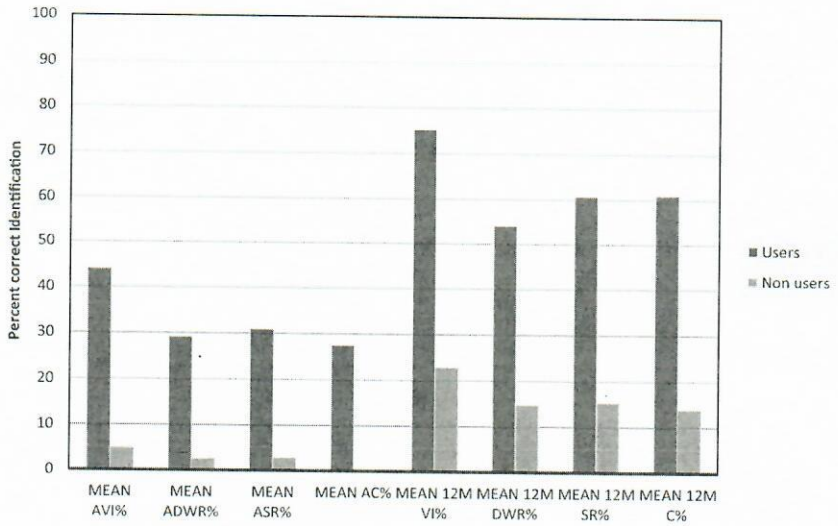

FIG. 1. Auditory performance at activation and after 12 months in both the user and nonuser groups. a, activation; C, common phrase comprehension; DWR, disyllabic word recognition; SR, speech recognition; VI, vowel identification.

TABLE 2. *Demographic and audiological parameters in the user group according to the degree of postoperative performance (n = 16)*

	High Performance	Intermediate Performance	Low Performance
Age (years)	47.3 ± 13.1	65.7 ± 8.1	38.7 ± 11.4
Tumor size (mm)	10.4 ± 4.2	5.7 ± 1.5	15.7 ± 4.0
No of sporadic VS	8	2	0
No of NF2	2	1	3
Preop PTA	58.3 ± 22.3 dB	46.3 ± 9.4 dB	21.7 ± 2.3 dB
Preop SDS	61 ± 44%	53 ± 50%	73 ± 25%
Postop PTA	50.7 ± 8.9 dB	60 ± 10 dB	80 ± 10 dB
Postop SDS	87 ± 10%	50 ± 10%	0%

PTA, postimplantation pure tone average; SDS, speech discrimination score; VS, vestibular schwannoma.

At 1-year postoperatively, the SDS was assessed in the user group. Only 16 patients were classified, of whom 10 (62.5%), three (18.75%), and three (18.75%) were high, intermediate, and low performers, respectively. All intermediate performers had NF2 with tumor size > 14 mm. Table 2 shows the demographic data and preoperative and postoperative audiologic findings of these patients. Figure 2 shows the other audiologic parameters at activation and after 12 months.

Six users had NF2, among whom the preoperative ipsilateral PTA was 39.2 ± 21 dB. Postoperatively, with CI and contralateral masking, the PTA was 69.2 ± 15 dB and SDS was 42% ± 47%. Two of the six patients with NF2 were high performers, one was intermediate, and three were low performers.

In the user group, the SSQ results showed that scores on the speech hearing subscale ranged from 2.9 to 7.4, with a mean of 5.3 ± 1.55. Scores on the spatial hearing subscale ranged from 2.2 to 9.2, with a mean of 5.4 ± 1.9. Scores on the quality subscale ranged from 2.7 to 9.2, with a mean of 5.8 ± 1.9. In the handicap test questionnaire, 14 (70%), four (20%), and two (10%) patients answered "never," "sometimes," and "often," respectively.

DISCUSSION

The first case of cochlear implantation following VS removal was reported by Hoffman et al. in 1992 in a patient with NF2 (16). Since then, cochlear implantation has been performed for many patients with NF2 (14,17–19) and in only the hearing ear of many patients with VS (20,21). Auditory rehabilitation in these cases includes either CI or auditory brainstem implant. In NF2 cases, when cochlear nerve function is preserved, cochlear implantation yields superior auditory performance. Vincenti et al. (18), compared the results of patients with NF2 receiving CI and those receiving auditory brainstem implant and found that sentence recognition scores were significantly better in the former. A similar outcome was reported in other studies (14,19). Cochlear implantation has many advantages compared to implantation of ABIs. In addition to being a simpler procedure with fewer risks and complications, cochlear implantation allows tonotopic stimulation of the auditory system, as the electrodes are placed close to the spiral ganglion cells, permitting an enhanced spectral resolution (14).

CI has been postulated to show suboptimal performance in SSD because of difficulties in integrating the normal acoustic signal and electrical stimulation. However, recent studies have shown that cochlear implantation with contralateral normal hearing had favorable results with significant improvement in sound localization and speech perception in noise. As a result, implanted patients showed improvement in the quality of life and quality of hearing (10,22,23). This has

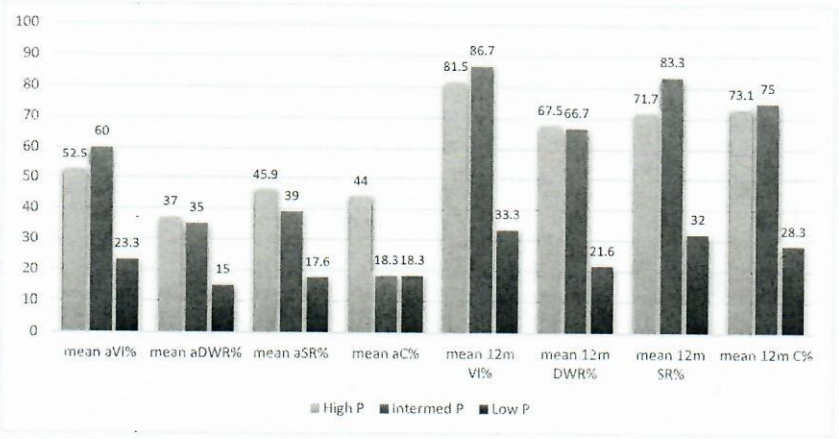

FIG. 2. Comparison of the hearing results at activation and after 12 months between the high, intermediate and low performance patients of the user group (n = 16). a, activation; C, common phrase comprehension; DWR, disyllabic word recognition; P, performance; SR, speech recognition; VI, vowel identification.

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encouraged the utilization of CIs for the auditory rehabilitation of SSD following VS surgery (21,24).

To our knowledge, the present series describes the largest number of patients with VS from a single institute managed with the translabyrinthine approach with simultaneous cochlear implantation. Our cases were a heterogenous group of both sporadic VS and NF2, and most of the patients had normal contralateral hearing with only 16 (seven users and nine nonusers) having asymmetric hearing loss. The contralateral hearing status did not affect the CI outcome. After at least 1 year postactivation, 80.5% of our patients received auditory stimuli with their implants. In the classified user group in our series, 81.25% of patients were high to intermediate performers. Our results are in accordance with Thompson et al. (25), who reported systematic review-evaluating patients with VS who were treated with translabyrinthine tumor removal and concurrent cochlear implantation. In their review, of the 41 patients identified, 85% had an auditory signal with the CI. Of the patients who reported speech recognition, 75% were high to intermediate performers.

In all patients in the present series, cochlear implantation was performed at the time of tumor removal. This has the advantage of avoiding another surgery with extra cost and a greater psychological burden on the patient. Early insertion of the implant and auditory rehabilitation lessen spiral ganglion degeneration (26,27). The disadvantage is the difficulty performing MRI for the tumor follow-up. However, the rate of tumor recurrences in our center is very low at only 0.05% (28). In case of suspicion, magnet removal can be performed under local anesthesia in a simple procedure. A recent study showed that proper MRI techniques and the use of recent MRI-compatible implants have significantly reduced artifacts in such cases and allowed precise imaging for tumor control in the presence of CIs (29). Cases of incomplete VS removal are considered to be a contraindication of concurrent cochlear implantation in our center. Delayed cochlear implantation has been advocated by some authors (30), who argue the possibility of promontory testing after 12 months to determine cochlear nerve functionality. Moreover, MRI tumor surveillance can be easily performed to exclude residual/recurrent tumor before implantation. However, variable degrees of cochlear ossification occur following the translabyrinthine approach (31,32). To overcome this, an intracochlear placeholder was inserted at the time of tumor removal to keep the cochlear patency (30,33).

Functional integrity of the cochlear nerve is a major concern in cochlear implantation in vestibular schwannomas surgery. Tumor dissection from the intimately related nerve may lead to anatomical or functional nerve injury. Tumor related factors, such as compression of the cochlear nerve in the internal auditory canal or pressure at the fundus of the canal, may lead to irreversible damage and spiral ganglion cell loss. After tumor resection, whether or not the nerve conducts electrical stimuli delivered by a CI should be determined. Different methods have been proposed for that purpose. Some authors have advocated promontory stimulation (30,34). However, the results are controversial because a negative response does not necessarily imply a lack of future benefit from the CI (35). A positive response does not predict the hearing outcome (36). Moreover, the test required the patient to be awake and therefore cannot be used for simultaneous tumor removal and CI placement. The electric auditory brainstem response (eABR) measurement has been performed using a stimulating electrode over the promontory (needle electrode), a golf electrode over the round window niche, and an intracochlear multichannel electrode. We have been utilizing intracochlear eABR measurements using a custom test electrode since 2015. The eABR measurements can be used with the translabyrinthine approach because of the accessibility of the cochlea via posterior tympanotomy. The intracochlear eABR correlates with the CI outcome (37,38). A recent study has shown that, compared to promontory electrodes, the intracochlear eABR results are slightly more detailed because of cleaner waveforms with fewer electrical stimulation artifacts (39). In our more recent cases, we determined the functional integrity of the nerve by eABRs and cochlear nerve action potential (CNAP). The eABR was detected using an intracochlear custom-made Med-El® test electrode (Innsbruck, Austria), which is requested in Europe under Custom-Made Device Regulations, 93/42/EEC (38). The electrode was inserted via posterior tympanotomy through the round window into the cochlea, and recording was performed using scalp electrodes. A multithreaded silver wire electrode was used to record the CNAP by measuring the electrical activity induced directly from the cochlear nerve using an electric stimulation through the intracochlear test electrode (Fig. 3). Positive results favor a high possibility of benefit from the CI. However, a negative response does not necessarily mean a lack of CI benefit, as it may be because of temporary contusion of the cochlear nerve due to surgical trauma which usually resolves in few months (35). In the present series, CNAP and eABR were measured after tumor removal. Kasbekar et al. (40) published a case report in which they had utilized eABR via an intracochlear test electrode for continuous cochlear nerve monitoring during translabyrinthine VS surgery. They tried to use CNAP for this task but failed to obtain useful information because of excessive artifacts. Theoretically, the additional benefit of continuous cochlear nerve monitoring using eABR or CNAP for preserving the cochlear nerve during the translabyrinthine approach should be validated in a larger number of patients. Further studies are required to correlate the eABR results with the CI outcomes and set the objective criteria for predicting a favorable outcome. Since we have used these tests only in our last patients, our data are still limited to reach valuable conclusions. Because of the limitations of electrical testing, we depend on the subjective evaluation of cochlear nerve preservation and degree of the trauma inflicted to the nerve during tumor removal. Excessive

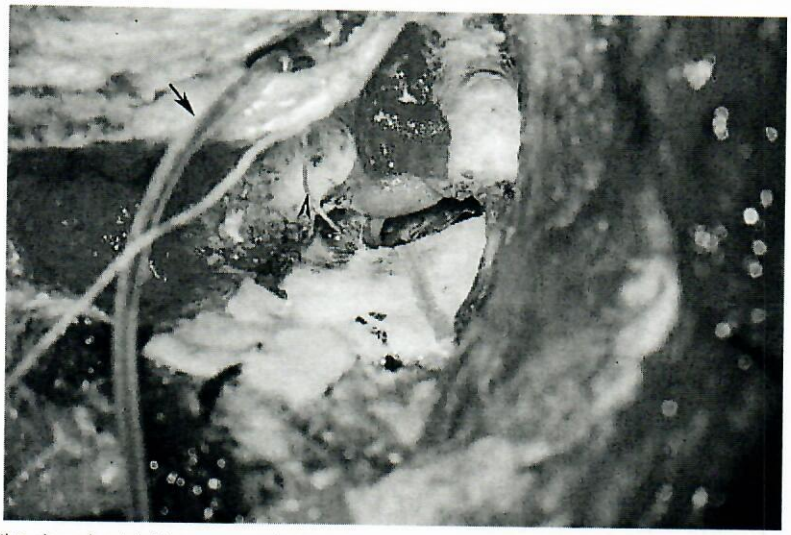

FIG. 3. Intraoperative view after total tumor removal. Note the intracochlear test electrode (arrow) already placed through a posterior tympanotomy and another electrode for measuring the CNAP (arrow-head) placed on the intact cochlear nerve.

retraction, stretching, or rough manipulation of the nerve portend a poor outcome.

In the current study, auditory stimulation was achieved in 33 patients (80.5%). However, not all patients continued using their implants. The classification of implant users and nonusers in the current study reflected the real benefits of this modality. Preoperative hearing might be a prognostic factor for the auditory outcome after CI. The preoperative hearing and SDS were significantly worse in the nonuser group (10 patients) compared to the user group (three patients), including patients with preoperative severe to profound SNHL. A possible explanation is that a bad preoperative hearing would reflect the degree of cochlear nerve affection and act as a bad indicator for the functional performance of cochlear implantation. This is in accordance with Lustig et al. (11), who suggested that neuronal damage from tumor growth is associated with poorer outcomes. This finding is in contrast with Bartindale et al. (41), who performed a systematic review of 45 patients of sporadic VS undergoing simultaneous cochlear implantation. Using a univariate regression analysis of factors that predict auditory outcome, they found that a good preoperative ipsilateral SDS was a negative predictor of SDS after CI placement.

In the current study, 21 (51.2%) patients were ultimately nonusers. The overall performance of cochlear implantation following VS resection is less than that achieved in patients with standard postlingual deafness (20,38,42). The incidence of CI nonusers was 2.8% among patients with postlingual bilateral deafness and 10% among adults with SSD (43,44). Neuronal injury from tumor growth or surgery may be associated with poorer outcomes (11). Therefore, this should be clearly explained to patients with VS preoperatively, and they should be encouraged to have realistic expectations, to use the implant, and to regularly attend rehabilitation sessions.

In the present study, a significant improvement in the hearing outcome was seen over time. Similar findings have been reported and are possibly explained by recovery of cochlear nerve neuropraxia that resulted from surgery (24). Recovery of cochlear nerve function following VS resection has also been shown on promontory stimulation testing (11,19). Furthermore, four of our patients turned into regular CI users after initially not benefiting from their device.

Patients with both sporadic VS and NF2 were included in the current study. NF2 tumors are often associated with poor surgical planes and adherence to the related nerves (14,45). This increases the likelihood of a poorer outcome. In the present series, six of eight patients with NF2 were users and showed no difference from patients with sporadic VS in CI performance. The sample size of patients with NF2 was too small for any meaningful analysis. A nearly similar outcome of the comparison between sporadic VS and NF2 has been reported previously (25).

Some of our patients would have been candidates for hearing-preservation surgery. In our center, we only consider patients having PTA < 30 and SDS > 70 as potential hearing-preservation candidates. However, we followed strict criteria for proceeding with hearing preservation. Factors advising against hearing preservation were: (1) a completely occupied internal auditory canal fundus, defined as the absence of cerebrospinal fluid in T2-enhanced MRI sequences; (2) excessive dilatation or enlargement of the internal auditory canal, defined as a minimum of 50% increase in the

anteroposterior diameter with respect to the contralateral side; and (3) age greater than 65 years in candidates undergoing the middle fossa approach (46).

Lloyd et al. (47) described their management of a few patients with NF2. In patients with serviceable hearing and tumor extension into the fundus, the translabyrinthine approach with concomitant cochlear implantation was preferred rather than the retrosigmoid approach with a hearing-preservation trial. Based on a literature review of patients with NF2 who received CIs and on their experience, the authors found a significantly more favorable CI outcome in patients who were managed with the translabyrinthine approach compared to those managed with the retrosigmoid approach. They attributed this to the fact that in the translabyrinthine approach, the cochlear nerve is exposed in its entirety, thereby helping avoid blind manipulations at the fundus of the internal auditory canal.

The SSQ is a self-reported measure of hearing disability that comprises 49 items covering three main parameters namely speech hearing, spatial hearing, and qualities of hearing. Our results were in the midscale and are comparable to those of single-sided deafness patients that were managed by cochlear implantation (44), and higher than values recorded from patients with nonrehabilitated hearing loss (49). Our results therefore indicate that CI showed improvement in speech understanding, sound localization, and sound quality. Using the HHQ, 14 out of 20 users reported no compromise in their daily activities, their social life, or their psychoemotional sphere.

Our study had certain limitations. The retrospective nature of the study limited the data collection to the availability in medical records. The SSQ questionnaire could not be obtained at the initial implant activation, and therefore, the variation of the outcome with time could not be assessed. However, the mean values of each of the three test parameters were comparable to patients with SSD who received CIs, as reported previously (44).

CONCLUSIONS

Simultaneous VS resection and cochlear implantation were a viable alternative for hearing rehabilitation in certain conditions. Although the results were suboptimal compared to standard cochlear implantation, many patients achieved a good auditory outcome. Future studies are warranted to establish more objective criteria to assess cochlear nerve function after VS resection and to predict which patients would benefit from this promising procedure.

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