Audiologic Outcomes of Simultaneous Translabyrinthine Resection and Cochlear Implantation

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**Introduction**

Vestibular schwannomas (VS) are benign tumors that arise from either the superior or inferior vestibular nerve and typically present with hearing loss, imbalance, and/or tinnitus. Surgical treatment of VS involves three approaches: retrosigmoid (RS), middle cranial fossa (MCF), and translabyrinthine (TL) approaches. RS and MCF approaches have the potential to preserve hearing; however reported rates of hearing preservation vary widely, ranging from 0-37% in one study to as high as 77% in another study for patients with small tumors and good preoperative hearing1,2. The TL approach, while resulting in complete hearing loss, provides improved surgical exposure with less brain retraction3. Due to the decreased cerebellar retraction and complete vestibular ablation, TL may result in decreased postoperative disequilibrium and ataxia compared with hearing preservation approaches.4,5

After TL excision of a VS, hearing rehabilitation has been mainly focused on transmitting the signal from the affected ear to the non-affected ear. Traditional treatment options have been Contralateral Routing of Signal (CROS) hearing aids and bone anchored hearing aids (BAHA). CROS hearing aids and bone conduction mechanisms have inferior hearing quality and speech perception in background noise as well as sound localization compared to a binaural state6.

Cochlear implantation (CI) has been demonstrated to be an effective treatment for single sided deafness (SSD) and has an increasing usage for this indication7–9. After RS and MCF resection of a VS, when hearing is not preserved, CI has been found to be a viable option for hearing treatment when the cochlear nerve remains intact10. TL excision of a VS with simultaneous or sequential CI has also been reported recently with promising results, however, there is limited prospective data regarding simultaneous implantation11. The purpose of this study is to evaluate the early audiologic results of TL resection of a VS and simultaneous placement of a CI in order to expand the relatively limited evidence currently available for this procedure.

**Methods**

This is a prospective study of non-randomized patients at a tertiary care neurotology center and was approved by the Institutional Review Board (IRB) at our institution. Patients with sporadic cerebellopontine angle tumors who elected to undergo TL excision of their tumor were invited to participate. Inclusion criteria included adult patients with a tumor size of 2 cm or less. Exclusion criteria included inability to spare the cochlear nerve during tumor dissection. All patients were given appropriate management options and elected to proceed with surgical management and concurrent CI. For a minor subset of the patients, cochlear implants were provided by Cochlear Corporation (New South Wales, Australia) when not covered by insurance.

**Preoperative Evaluation**

Preoperatively, audiologic testing was performed in the following conditions: AzBio sentence testing in quiet with 0 degree azimuth, AzBio sentence testing in +10 and +5 signal to noise ratio (SNR) with speech and noise at 0 degrees azimuth presented bilaterally. The consonant-nucleus-consonant (CNC) testing was presented to the affected ear independently in quiet at 0 degrees azimuth. In order to minimize the effect of the opposite ear, the non-test ear was fit with an earplug and a supra-aural headphone. In addition, all subjects were asked to complete the following surveys: the Speech, Spatial and Qualities of hearing scale (SSQ) to assess hearing across multiple domains, the Tinnitus Handicap Inventory (THI) to determine severity of a patient’s tinnitus, and the Dizziness Handicap Inventory (DHI) to assess for the patient’s degree of dizziness12,13. For the SSQ, S1 represents the speech hearing section, S2 represents the spatial hearing section, and Q represents the qualities of hearing section. A higher score in the THI and DHI represent a larger burden of disease, while a higher SSQ score represents improved hearing capabilities.

**Surgical Technique**

All patients underwent standard TL surgical resection with gross total tumor resection. After the tumor was excised, a cochleostomy was performed in the typical anteroinferior location and the CI was inserted utilizing the off-stylet technique. The middle ear and the eustachian tube were then packed with fascia and muscle and the mastoid defect was filled with either hydroxyapatite cement or abdominal fat.

One patient did undergo CI at a sequential surgery, with implantation approximately one year after surgical excision of the tumor, which pathology revealed as a meningioma (patient 1). The same neurosurgeon and neurotologist team were involved in all tumor removals and CI. Nucleus Profile Plus with Contour Advance (CI612, Cochlear Corporation) were used in all but one case (patient 4), in which a HiRes Ultra 3D Mid-Scala (Advanced Bionics) implant was used.

**Postoperative Evaluation**

The patients underwent postoperative follow up at 1 week and 1 month with CI activation performed at the second visit. Further programming visits were completed at 1 and 3 month post-activation. The preoperative testing surveys were also repeated at each of the visits starting at 1 month post-activation. Due to COVID-19, some patients were unable to attend their follow up testing. If this was the case, testing for this time point was skipped and the next time point was tested.

In addition to testing results, the patients were classified into their functional performance status similar to previous methods based on open-set recognition: low performance (0-33%), intermediate performance (34-66%), and high performance (67-100%)14,15.

Patients were asked to wear their processor on a daily basis and encouraged to read out loud at home for a minimum of 30 minutes per day. Patients were asked to use an ear plug in their non-surgical ear for at least half of their reading sessions.

**Statistical Analysis**

T-test and logistic regression models were used to evaluate for statistical differences using Excel. A significance value of .05 was used for all analysis.

**Results**

Fourteen patients underwent surgery during this time period. Ten had at least 3 months of audiologic follow up to this point. Patient demographic data for these patients can be seen in Table 1. Average tumor size was 7.9 mm (Range 3-16mm). Average age of the patients was 52.6 years (Range 35-64).

**Pre- and Postoperative Speech Intelligibility**

Preoperatively, the mean speech understanding for AzBIO sentence testing in quiet was 97% (range 89%-100%), 90% (range 61%-99%) for +10 SNR, and 82% (range 38%-96%) for +5 SNR. Mean CNC testing showed a mean of 31% (range 2%-68%) speech understanding on the affected side. Preoperative hearing data and scattergram can be seen in Table 2 and Figure 1, respectively.

Three month post-activation data and pre- and postop comparisons can be seen in Table 3 and 4, respectively. There was a statistically significant improvement in the +10 and +5 SNR, and in quiet AzBIO as well as CNC testing compared to the preoperative testing (p<.05).

Regression data for preoperative CNC score, tumor size and their relationship to postoperative CNC score revealed R-values of .057 and .063, respectively.

**SSQ, THI, and DHI Questionnaires**

Preoperative and 3 month post-activation SSQ scores can be seen in Tables 2 and 3, respectively. Overall, total SSQ increased from 11.8 to 14.4, with neither this, nor individual domains being significantly different between the two groups.

The pre- and postoperative DHI and THI scores can be seen in Tables 2 and 3, respectively. The mean THI score for the preoperative group was 41.3 (range 0-74). At 3 month testing the mean THI was 23.3, a significant decrease from preoperative testing (p=.01), demonstrating a reduction in tinnitus in these patients. There was no significant difference in DHI between the groups, multiple patients did have large improvements (>15) on DHI score in the postoperative period (Patients 2,5,9,10), while 2 patients had a greater than 10-point worsening of their DHI scores.

**Complications**

Two of our patients developed a delayed facial nerve weakness, one had complete recovery while the other had incomplete recovery to House-Brackmann grade 3/6 that is currently being observed at 11 months postoperatively.

**Discussion**

Binaural hearing is a significant benefit of CI compared to CROS and BAHA for those with SSD16. Previous studies of CI after VS excision have evaluated patients with NF2 who generally have restricted hearing on the contralateral side. Rooth et al. examined TL excision of VS with concurrent CI in patients with normal or near normal contralateral hearing. and demonstrated significant benefit in sound localization as well as speech in noise17. Our study, similarly, suggests a significant improvement in AzBIO in quiet, +10 and +5 SNR as well as CNC testing between the preoperative and postoperative groups. Importantly, this demonstrates an improvement in speech recognition with background noise postoperatively, even compared to their preoperative, binaural state.

Sanna et al. also completed a prospective study of patients that received simultaneous TL excision of VS and CI. There was a significant improvement in the binaural squelch effect in their study, inferring an improved ability to hear in background noise for patients using the CI18. Sound localization was found to be significantly improved in the aided condition compared to the unaided at both follow up points18. The SSQ questionnaire in our study, specifically the spatial hearing (S2) section, relates with similar self-reported sound localization ability. Our patients noted a non-significant improvement in their S2 from 3.37 to 4.51 with short term data.

The previous two studies were included in a systematic review by Thompson et al. which identified 41 patients that have undergone concurrent CI with removal of a VS19. Sixteen patients had reporting of their open-set testing. Utilizing the functional outcome measurements, they found that 4 patients were lower performers, 4 intermediate performers and 8 patients were high performers19. Based on CNC score testing at 3 months post-activation, 5 out of 10 (50%) of our patients were intermediate performers, with 2 improved from initial low performance. The 4 other patients were high performers (40%), with 1 patient being a low performer (10%). In general, our data shows great improvement in open-set speech recognition after CI. Similar hearing outcomes have been noted in CI for single sided deafness due to other causes7.

Rooth et al. also demonstrated a significant improvement in tinnitus outcomes based on THI scores17. Our patients similarly experienced a decrease in THI from 41.3 preoperatively to 23.3 at the 3 month postoperative testing (p=.01). Tinnitus may be a significant symptom for patients regardless of tumor size and has been shown to strongly affect the quality of life of patients with VS20,21. While TL approach to a VS may lead to an improvement of tinnitus on its own, a significant number of patients still suffer from high grades of tinnitus after surgical excision of a VS22,23. CI has been used to achieve tinnitus improvement in patients with SSD and appears to be effective in treating those after VS resection24. While our cohort did show improvement, it is not entirely clear whether this was due to the translabyrinthine approach or the CI. Future studies may be performed to further answer this question.

Ideal candidacy of VS patients for TL with CI has yet to be identified given the relative paucity of data. Of fundamental importance to the success of this procedure is the preservation of the cochlear nerve both preoperatively as well as intraoperatively. Tumor size has been implicated as a factor affecting outcomes in hearing preservation surgery and may impact impact hearing outcomes of simultaneous TL resection with CI25 While tumor size was not be found to be correlated with postoperative hearing outcomes in the current study, further investigation with a larger sample size are warranted. Additionally, preoperative hearing scores were not correlated with postoperative hearing outcome in our cohort, but should be further evaluated in larger future studies. Another factor of interest is the duration of hearing loss, which may impact the success of good hearing outcomes with CI. Electrophysiologic evaluations of the cochlear nerve should also be investigated further to stratify candidates for simultaneous CI. Cochlear nerve action potential (CNAP), auditory brainstem response (ABR), and electrical promontory stimulation (EPS) have been investigated as potential methods with mixed results, including cases where there was no response to cochlear nerve stimulation in patients that underwent a successful CI26–28.

A concern with simultaneous tumor excision and CI is the difficulty with tumor follow up afterwards as MRI is the preferred method of clinical follow up for VS. CI has been found to be safe to use with MRI up to 1.5 Tesla, however, they caused an artifact that averaged 6.6 x 4.8 cm in one study29. Despite this large artifact, in the majority of instances the ipsilateral IAC can be at least partially visualized29. Carlson et al. reviewed CI in patients with intracochlear schwannomas without surgical excision with the ipsilateral inner ear and skull base being adequately visualized30. If CI is delayed due to concern for surveillance, it is generally recommended that a dummy electrode is placed into the cochlea due to the high rates of cochlear fibrosis18,31; however, in the case of patient 1, CI was performed without difficulty one year after the initial tumor resection. Audiologic outcomes were similar in patients undergoing simultaneous CI and delayed CI after translabyrinthine resection in a recent systematic review11

Although some of the patients in the current study had smaller tumors and good preoperative hearing, they preferred to undergo translabyrinthine surgical resection rather than observation or a hearing preservation approach. One patient specifically, given the option of a retrosigmoid approach, opted for translabyrinthine approach due to a family member with severe headaches after a similar surgery.

While the goal of this study is to present early audiologic outcomes, this is also one of the limitations given that CI performance can improve progressively long term18. Our study is also a single institution and single surgeon study, which may limit is applicability to all populations. Another limitation of our study includes inclusion of two patients with inner ear VS, one with intralabyrinthine and one with intracochlear. Both of these patients underwent surgical excision with labyrinthectomy and one with an extended cochleostomy in order to removal the entire tumor.

**Conclusion**

CI is a valid treatment for the hearing loss after translabyrinthine excision of VS. These patients have improved hearing in background noise and tinnitus compared to their preoperative state. Anatomical cochlear nerve preservation is required but is not the only factor affecting hearing outcomes with CI. While there was no significant difference, the SSQ questionnaire is unique to our study and may be an indicator of binaural benefit in CI patients. Longer follow up times and increased patient population are required for further evaluation of SSQ and other prognostic factors. Further research into intraoperative cochlear nerve monitoring may also yield a helpful predictive indictor in the future.

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Figure 1: Preoperative Hearing Scattergram



|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Table 1 |  |  |  |  |  |  |  |
| Patient | **Device** | **Affected Ear** | **Age (years)** | **Sex** | **Tumor Location** | **Tumor size (mm)** | **Concurrent CI** |
| 1 | Cochlear | right | 35 | Female | CPA with IAC involvement | 16 | No |
| 2 | Cochlear | right | 64 | Male | intracanalicular | 5 | Yes |
| 3 | Cochlear | right | 63 | Female | intracanalicular | 9 | Yes |
| 4 | AB | right | 53 | Male | intracanalicular | 4 | Yes |
| 5 | Cochlear | right | 53 | Male | intracanalicular | 8 | Yes |
| 6 | Cochlear | left | 36 | Male | intracanalicular | 3 | Yes |
| 7 | Cochlear | left | 61 | Male | intracanalicular | 9 | Yes |
| 8 | Cochlear | right | 67 | Male | CPA with IAC involvement | 14 | Yes |
| 9 | Cochlear | right | 43 | Female | intralabyrinthine | 5 | Yes |
| 10 | Cochlear | right | 51 | Female | intracochlear | 6 | Yes |

Table 1: Patient Demographics

CPA: Cerebellopontine Angle; IAC: Internal auditory canal; AB: Advanced Bionics

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Table 2 |  |  |  |  |  |  |  |  |  |  |  |
| **Patient** | PTA (dB HL) | WRS (%) | AZBIO Quiet | AZ BIO +10 SNR | AZ BIO +5 SNR | CNC Affected | **SSQ - S1** | **SSQ- S2** | **SSQ - Q** | **THI** | **DHI** |
| 1 | 0 | 100 | 98% |   | 95% | 2% | 5.14 | 3 | 8.28 | 4 | 16 |
| 2 | 58.75 | CNT | 90% | 61% | 38% | 10% | 4.1 | 2.7 | 4.89 | 50 | 54 |
| 3 | 25 | 96 | 94% | 90% | 68% | 68% | 5.93 | 5.76 | 7.61 | 64 | 0 |
| 4 | 42.5 | 92 | 100% | 94% | 96% |   |   |   |   |   |   |
| 5 | 63.75 | CNT | 89% | 86% | 91% | 6% | 1.14 | 1.29 | 1.78 | 48 | 30 |
| 6 | 57.75 | 76 | 100% | 93% | 90% | 54% | 2 | 1.12 | 2.72 | 62 | 32 |
| 7 | 42.75 | 60 | 100% | 98% | 94% | 36% | 7.29 | 7.94 | 7.67 | 0 | 14 |
| 8 | 68.75 | 40 | 99% | 90% | 90% | 52% | 1.79 | 2.65 | 7.17 | 20 | 0 |
| 9 | 73.75 | 84 | 100% | 99% | 89% | 24% | 2.93 | 3.65 | 4.28 | 74 | 60 |
| 10 | 68.75 | 32 | 98% | 99% | 69% | 30% | 6.86 | 2.24 | 6.06 | 50 | 40 |

Table 2: Preoperative audiologic evaluation

CNC Affected: Consonant-Nucleus-Consonant testing of affected ear

SSQ: Speech, Spatial, Quality of Hearing Scale - S1: Speech Subsection, S2: Spatial Subsection, Q: Quality subsection

THI: Tinnitus Handicap Inventory

DHI: Dizziness Handicap Inventory

CNT: Cannot Test

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Table 3 |  |  |  |  |  |  |  |  |  |  |
| **Patient** | **AzBio in quiet** | **AzBio +10 SNR** | **AzBio +5 SNR** | **CNC Affected** | **Functional Status** | **SSQ - S1** | **SSQ- S2** | **SSQ - Q** | **THI** | **DHI** |
| 1 | 100% | 100% | 97% | 80% | HP | 3.71 | 2 | 6.39 | 0 | 18 |
| 2 | 99% | 92% | 61% | 46% | IP | 6 | 4.53 | 6.39 | 0 | 8 |
| 3 | 100% | 99% | 96% | 84% | HP | 4.86 | 3.35 | 5.22 | 34 | 22 |
| 4 | 100% | 100% | 100% | 60% | IP | 5.5 | 3.35 | 5 | 68 | 52 |
| 5 | 99% | 97% | 96% | 44% | IP | 4.14 | 4.06 | 4.44 | 6 | 14 |
| 6 | 100% | 100% | 96% | 46% | IP | 3.25 | 1.82 | 3.33 | 62 | 58 |
| 7 | 100% | 100% | 99% | 84% | HP | 8 | 8 | 7.89 | 0 | 12 |
| 8 | 100% | 100% | 97% | 34% | LP |   |   |   |   |   |
| 9 | 100% | 100% | 100% | 62% | IP | 5.14 | 4.26 | 5.19 | 34 | 0 |
| 10 | 100% | 96% | 100% | 80% | HP | 9.62 | 9.23 | 9.61 | 6 | 4 |

Table 3: 3 Month post-activation audiologic data

CNC Affected: Consonant-Nucleus-Consonant testing of affected ear

Functional Status: HP: High Performer (67-100%), IP: Intermediate Performer (34-66%), LP: Low Performer (0-33%)

SSQ: Speech, Spatial, Quality of Hearing Scale - S1: Speech Subsection, S2: Spatial Subsection, Q: Quality Subsection

THI: Tinnitus Handicap Inventory

DHI: Dizziness Handicap Inventory

|  |  |  |  |
| --- | --- | --- | --- |
| Table 4 |  |  |  |
|  | Preoperative | Postoperative | p-value |
| AzBio Quiet | 97% | 100% | 0.037\* |
| AzBio +10 SNR | 90% | 98% | 0.034\* |
| AzBio +5 SNR | 82% | 94% | 0.006\* |
| CNC Affected | 31% | 62% | 0.014\* |
| SSQ - S1 | 4.13 | 5.58 | 0.088 |
| SSQ- S2 | 3.37 | 4.51 | 0.272 |
| SSQ - Q | 5.61 | 5.94 | 0.390 |
| THI | 41.33 | 23.33 | 0.010\* |
| DHI | 27.33 | 20.89 | 0.256 |

Table 4: Pre- and postoperative comparison

SNR: Signal to noise ratio

CNC Affected: Consonant-Nucleus-Consonant testing of affected ear

SSQ: Speech, Spatial, Quality of Hearing Scale - S1: Speech Subsection, S2: Spatial Subsection, Q: Quality Subsection

THI: Tinnitus Handicap Inventory

DHI: Dizziness Handicap Inventory