Received: 13 July 2024 | Accepted: 28 July 2024

DOI: 10.1002/lio2.1319

ORIGINAL RESEARCH

Laryngoscope Investigative Otolaryngology

Simultaneous cochlear implantation with early endoscopic surgery in small acoustic neuroma

Seong Hoon Bae MD, PhD[1] | Ludovica Battilocchi MD[2,3] | Nam Yunbin MD[4] | Gerard Lapina MD[5] | Ji Min Yun MD[4] | In Seok Moon MD, PhD[4]

[1]Department of Otorhinolaryngology, Gangnam Severance Hospital, Yonsei University College of Medicine, Seoul, South Korea

[2]Department of Otolaryngology and Head and Neck Surgery, Fondazione IRCCS Ca' Granda Ospedale Maggiore Policlinico, Milan, Italy

[3]Department of Clinical Sciences and Community Health, University of Milan, Milan, Italy

[4]Department of Otorhinolaryngology, Yonsei University College of Medicine, Seoul, South Korea

[5]Rizal Medical Center, Pasig, Philippines

Correspondence
In Seok Moon, Department of Otorhinolaryngology, Yonsei University College of Medicine. 50 Yonsei-ro, Seodaemun-gu, Seoul, 03722, South Korea.
Email: ismoonmd@yuhs.ac

Funding information
Yonsei University College of Medicine, Grant/Award Number: 6-2023-0088; National Research Foundation of Korea, Grant/Award Number: RS-2023-00253371

Abstract

Objectives: The exclusive endoscopic transcanal transpromontorial approach (EETTA) has recently been developed for the removal of small-sized acoustic neuromas in the labyrinth (intralabyrinthine schwannoma [ILS]) or internal auditory canal (IAC). Although small tumors that meet the indications for EETTA are also good candidates for cochlear implantation (CI), there are few reports on CI after schwannoma removal using EETTA. Here we present an outcome of patients who underwent simultaneous EETTA and CI.

Methods: Five patients (two with IAC fundus tumors and three with ILS) who underwent simultaneous EETTA and CI between 2020 and 2022 were retrospectively enrolled. Their medical charts and test results were reviewed.

Results: After at least 12 months of follow-up, there were no severe surgical complications such as meningitis, infection, or skin necrosis. Four of the five patients responded to auditory stimulation. Three out of four auditory-responsive patients scored >80% on sentence recognition.

Conclusion: Simultaneous EETTA and CI are feasible for the treatment of ILS and IAC fundus tumors. Preservation of the cochlear nerve and modiolus is important for favorable CI outcomes. Therefore, ILS and IAC fundus tumors in patients with nonserviceable hearing should be surgically removed as early as possible to enable proper hearing rehabilitation with CI.

Level of Evidence: Level 4.

KEYWORDS
acoustic neuroma, cochlear implant, endoscopy, Schwannoma

1 | INTRODUCTION

Acoustic neuroma (AN), also known as vestibular schwannoma, is a benign tumor that originates from Schwann cells of the vestibular or cochlear nerves.[1] Most of them are located in the internal auditory canal (IAC); however, some can be found inside the labyrinth (intralabyrinthine schwannoma [ILS]). Regardless of their location, ANs frequently result in sensorineural hearing loss, and 75% of them eventually result in nonserviceable hearing.[2] Additionally, hearing loss is regarded as an inevitable and irreversible consequence, although

several treatment modalities including "watch and wait," gamma knife surgery (GKS), and hearing preservation surgery, have been attempted.[3–6]

Furthermore, cochlear implantation (CI) has been implemented in patients with AN with hearing loss after surgery in several groups.[7] The results are promising, as approximately 50% of recipients achieved open-set speech; however, the treatment guidelines still do not discuss hearing rehabilitation after surgery or GKS.[8,9] Moreover, an exclusively endoscopic transcanal transpromontorial approach (EETTA) has recently been developed for small sized IAC AN or ILS removal.[10,11] However, because EETTA inevitably disrupts the bony labyrinth, CI with EETTA can be challenging. Consequently, reports about CI after schwannoma removal using EETTA are lacking. Nonetheless, small tumors that meet the indications for EETTA are good candidates for CI due to a higher chance of cochlear nerve preservation compared to large tumors with IAC intrusion.[12,13]

Therefore, in this case series, we present the results of patients who underwent simultaneous EETTA (two IAC fundus tumors and three ILS) with CI. This study aimed to discuss the feasibility and results of simultaneous CI and EETTA surgery. Furthermore, we aimed to propose a novel treatment strategy for small tumors near or inside the labyrinth.

2 | METHODS

Five patients who underwent simultaneous EETTA and CI between 2020 and 2022 were retrospectively enrolled and their medical charts and test results were reviewed. The CI device and electrode type were determined based on the surgeon's preference. I.S.M (patients 1, 2, 3, and 5), and S.H.B. (patient 4) performed the surgeries. A conventional CI surgery was performed using the traditional transmastoid approach with a surgical microscope. In brief, a retroauricular skin incision was made along the auricle, and then the Palva flap was elevated. The external auditory canal (EAC) skin was not elevated except one patient who A canal wall up mastoidectomy was performed using a surgical drill, and the facial nerve was identified. A posterior tympanotomy was performed, and then the electrode was introduced into the round window. The insertion could be monitored using an ear endoscope. In two cases, the electrode was attempted to be placed on the EAC wall without undergoing mastoidectomy. A bony groove was drilled for the electrode on the cortical mastoid bone and the posterior EAC wall. The electrode was then introduced into the round window via the EAC and placed in the groove. The electrode in the groove was supported with fascia and bone dust.

Auditory performance was evaluated preoperatively and annually after switching on the device. During the postoperative follow-up period, aided pure-tone audiometry and speech audiometry were performed in the sound field of a soundproof booth. The sound field consisted of two loudspeakers located at a distance of 1 m and at ±45° from the subject's head. We adopted a wireless speech test because all enrolled patients had residual hearing on the healthy side.[14] In brief, we used the "Bluetooth" function of an iPad (Apple Inc., Cupertino, CA, USA) to transmit the recorded sound signal from the iPad to a speech processor. Thus, the patients' healthy sides were excluded. No statistical analyses were performed. This study was approved by the institutional review board of Severance Hospital (project number: 4-2023-1367). The requirement for informed consent was waived owing to the retrospective nature of the study.

3 | RESULTS

3.1 | Preoperative information of patients

Five patients who underwent simultaneous EETTA with CI had small tumors (Koos grade 1) (Table 1); two IAC schwannomas, and three cochlear schwannomas. Hearing function was evaluated using pure tone and speech audiograms, and all patients had nonserviceable hearing. Patients were informed about the treatment options, including "watch and wait," GKS, open surgery, and EETTA. They opted to simultaneously undergo CI with EETTA after a thorough discussion with the clinician. The implant device and electrodes were selected according to the surgeon's preference; two perimodiolar and three lateral wall-type electrodes were used.

3.2 | Outcome of surgery

There were no severe surgical complications, such as meningitis, infections, or skin necrosis. However, the implant in Patient 1, the first patient to undergo simultaneous EETTA and CI, did not respond to auditory stimulation. Temporal bone computed tomography (CT) of this patient revealed a slightly deep-inserted electrode; however, the cochlear modiolus and electrode positions were normal. Therefore, the implants in Patient 1 were removed. In Patient 2, the electrode, which was placed in the EAC without mastoidectomy, was exposed to EAC 10 months after surgery. Nevertheless, the exposed electrode was preserved without revision surgery because the patient was asymptomatic.

The remaining four successfully implanted patients showed a good response to auditory stimulation, although their monosyllabic word recognition scores varied (Figure 1). In addition, speech intelligibility tests were performed using a wireless connection method to completely exclude normal ears. Three out of four patients scored >80% on sentence recognition.

3.3 | Surgical procedures of simultaneous EETTA and CI

Surgery for tumors located in the IAC fundus (Patients 1 and 2) was conducted as previously reported.[15] Tympanic membrane was elevated with a skin flap using endoscopy, the middle ear was exposed, and the posterior bony annulus was partially removed for a better surgical view and working space. The incudostapedial joint was separated

TABLE 1 Patients who underwent simultaneous EETTA and CI.

Patient Number	Sex	Age	Side	Tumor location	Tumor size (mm)	Koos Grade	Preop PTA4 (dB)	Preop WRS (%)	Operation	Electrode	F/u months (last hearing test)
1	M	62	Lt	Fundus	4	1	71	6	EETTA + CI	Lateral (EAC)	1 (removed)
2	M	40	Lt	Fundus, Vestibule, Basal turn	7	1	109	6	EETTA + CI	Lateral (EAC)	30
3	F	54	Rt	Middle turn	N/A	1	118	0	EETTA + CI	Lateral	12
4	M	27	Lt	Basal turn	N/A	1	98	10	EETTA + CI	PM	12
5	M	46	Rt	Basal-Middle turn	N/A	1	104	0	EETTA + CI	PM	16

Abbreviations: CI, cochlear implant; PM, perimodiolar; EAC, electrode placed in the external auditory canal without mastoidectomy; EETTA, exclusive endoscopic transcanal transpromontorial approach; F, female; Lt, left; M, male; N/A, Not applicable; PTA4, average pure tone audiometry (0.5, 1, 2, 4 kHz); Rt, right; WRS, word recognition score at the most comfortable level.

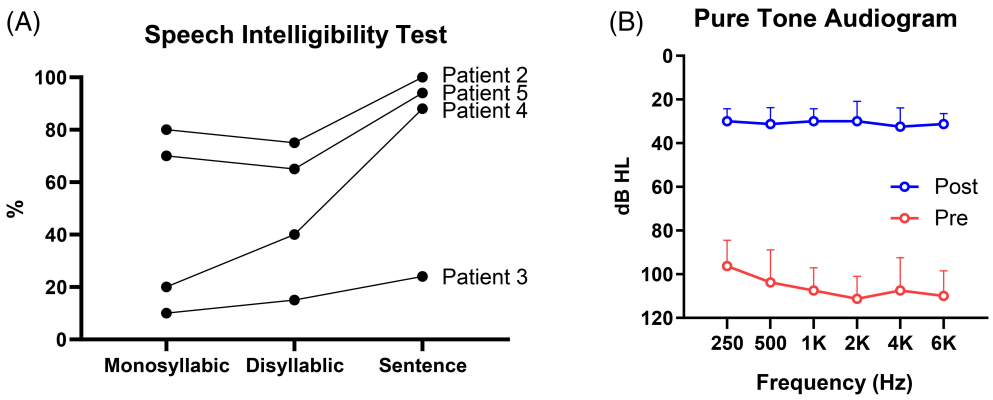

FIGURE 1 Outcomes of simultaneous cochlear implants with exclusive endoscopic transcanal transpromontoreal approach (EETTA) tumor removal. (A) The speech intelligibility test using the wireless connection. (B) Pure-tone audiogram. Hollow circles indicate mean value and error bars indicate standard deviation. Pre: Before surgery. Post: After surgery aided by the cochlear implant.

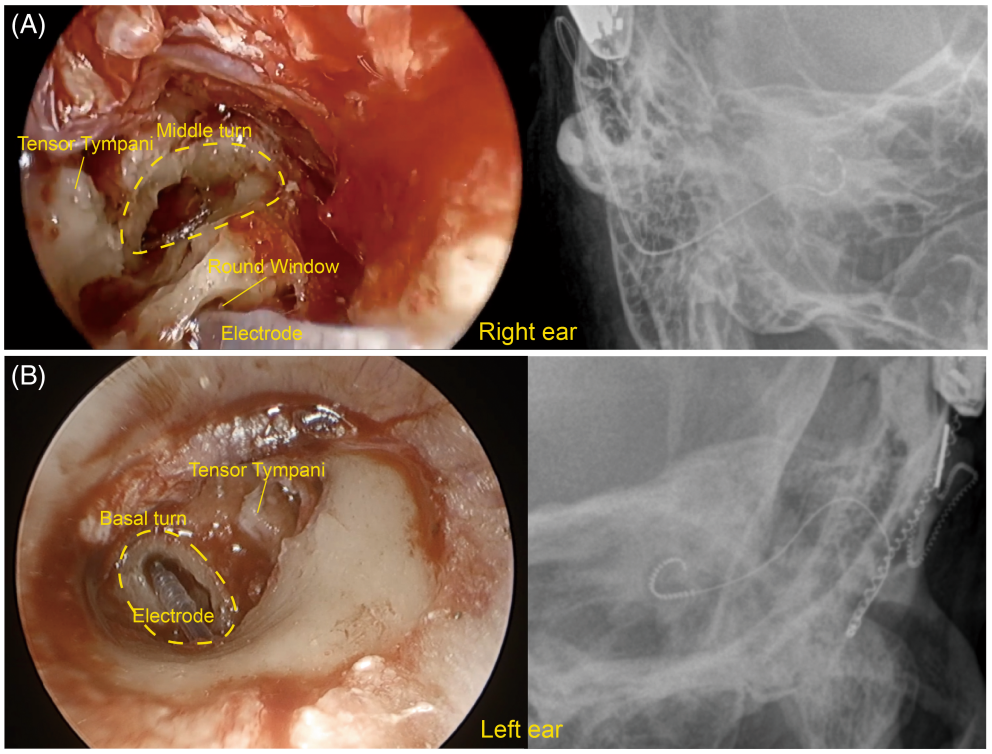

FIGURE 2 Representative images of surgical and postoperative transorbital view radiography. (A) Images of Patient 3 who had a mid-turn tumor. Lateral type electrode is identified. (B) Images of Patient 4 who had a basal-turn tumor. Perimodiolar type electrode is identified.

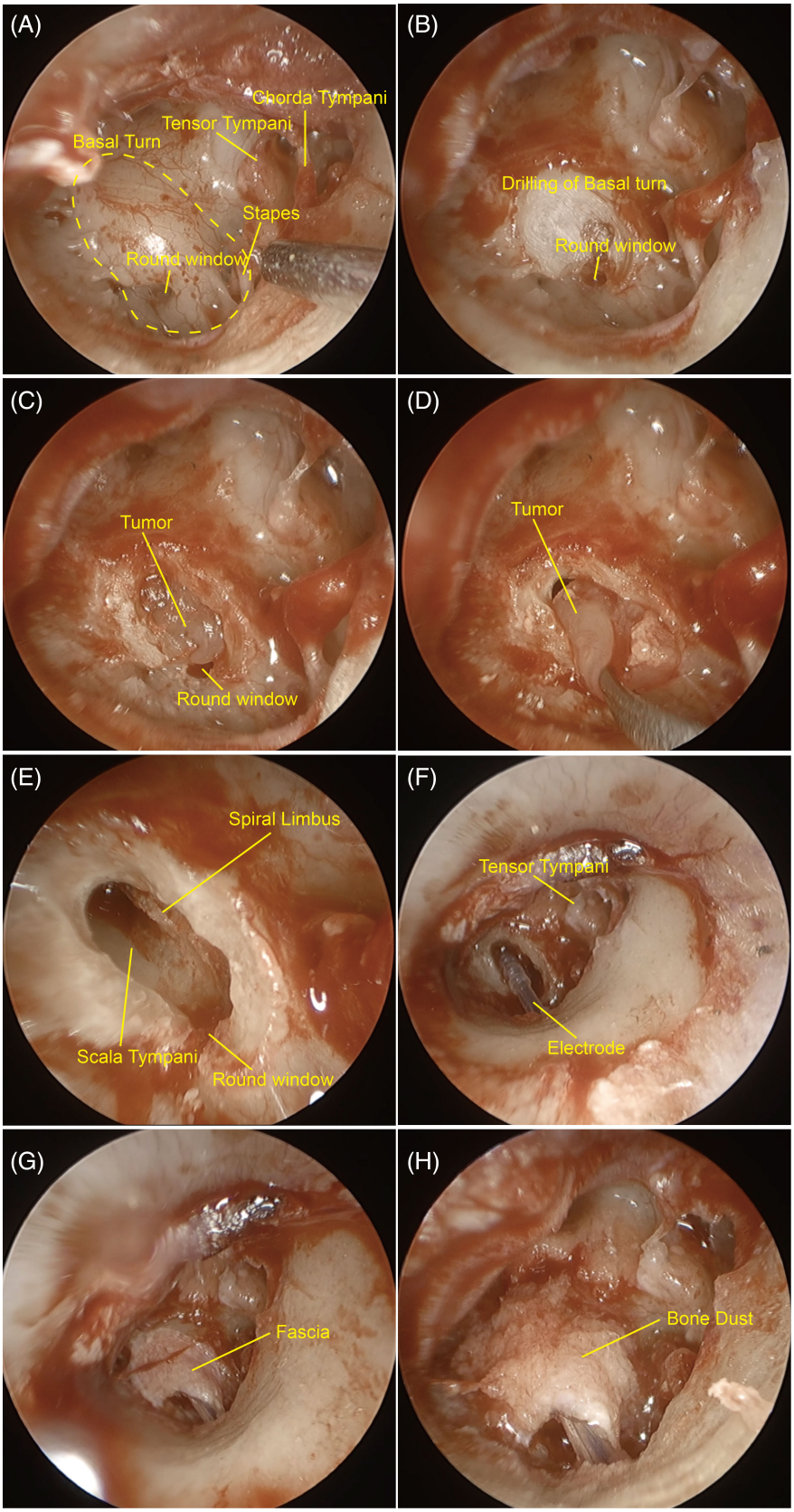

FIGURE 3 Serial endoscopic images of surgery for Patient 4.

and the malleus and/or incus were removed. The promontory was carefully drilled carefully to expose tumor. In the case of mid-turn ILS (Patient 3), the basal turn and round window were preserved for landmarks and electrode stabilization (Figure 2A). In the case of basal-turn ILS (Patients 4 and 5), the round window was removed (Figure 2B). The tumor was removed using suction and picking after

the wide opening of the promontory. Specific care was taken to preserve the modiolus during all procedures. A dummy electrode was inserted to verify the presence of any remaining tumor and ensure a clear passage for the actual electrode. For Patients 3, 4, and 5, a canal wall up mastoidectomy without EAC flap elevation was performed, followed by CI device placement beneath the temporalis muscle. The electrode was inserted into the round window after the posterior tympanotomy. During electrode insertion, the surgeon observed the electrode position inside the cochlea in the EAC using endoscopy. (Figure 3 and Supplementary Video S1) After complete insertion of the electrode, the promontory defect was covered with a cartilage composition graft or fascia with bone dust.

4 | DISCUSSION

CI can be simultaneously performed with EETTA for IAC fundus tumors or ILS, even though EETTA inevitably disrupts the cochlear bony capsule. Furthermore, the audiological outcome of simultaneous CI with EETTA can be successfully achieved, with sentence scores reaching up to 100%. A perimodiolar-type electrode (Patients 4 and 5) seems to be preferred because the lateral wall of the cochlea is partially removed; however, the lateral-type electrode (Patients 2 and 3) also showed good results. The most crucial factor in achieving successful CI seems to be the conservation of the cochlear nerve and modiolus.

To the best of our knowledge, only a few single case reports have been published, and this is the first case series to report EETTA and concurrent CI.[15,16] In addition, several previous studies have reported simultaneous or sequential CI with vestibular schwannoma removal. Patients after ILS removal have frequently been reported as good candidates for CI with respect to cochlear nerve preservation.[17–22] Furthermore, Laborai et al. suggested performing CI without tumor removal.[23] The audiological outcomes of patients who underwent schwannoma removal with CI were also promising; the majority successfully perceived audiological stimulation, with up to 75% achieving monosyllabic word recognition.[20] In this study, Patient 2, who showed the best results, also scored 80% for monosyllabic words and 100% for sentence recognition, consistent with previous reports.

ILS and small tumors limited to the IAC fundus are good candidates for EETTA.[24–26] Because the tumor can be successfully removed with a better surgical view than the transmastoid approach, when considering the angle of the cochlear modiolus. Moreover, the low invasiveness of the EETTA is comparable to that of the transcanal approach using surgical microscopy. Although EETTA should be performed single-handedly, it can provide better surgical vision and reduce operation and postoperative recovery time compared to transcanal approach using microscopy.[24,25] The major drawback of EETTA and microscopic transcanal approach is the limitation of IAC exposure; therefore, a combined approach would be helpful for advanced cases.[27] Another key advantage of EETTA is the absence of a retroauricular skin incision or mastoidectomy. However, this advantage is lost when CI is implanted simultaneously. Several groups have also successfully placed CI electrodes in the EAC using a transmeatal approach.[28–31] In our study, the electrode was eventually exposed during long-term follow-up (Patient 2). Therefore, in future studies, transmeatal CI combined with EETTA should be attempted to ensure minimally invasive surgery.

Given previous reports and this study regarding outcomes of CI with schwannoma removal, the "watch and wait" strategy for ILS and fundus small tumor is not recommended. If a patient's hearing is nonserviceable, early surgical removal is required to guarantee successful hearing rehabilitation with a CI. Moreover, since up to 60% of the tumors grow during the 'watch and wait' period, it becomes increasingly difficult to completely surgically remove them while preserving the modiolus and cochlear nerve.[32] Furthermore, studies have reported up to 33% of patients worsened hearing in ILS tumors using GKS.[33,34] This suggests that GKS has the potential to cause collateral damage to the cochlear nerve periphery, which is crucial for receiving electric stimulation from a cochlear implant. Consequently, the most appropriate method before hearing rehabilitation with CI seems an early surgical removal to preserve the cochlear nerve and modiolus.

Nonetheless, this study had some limitations. First, this was a small case series without a statistical analysis. Second, there were no long-term follow-up results for tumor recurrence. Third, we did not discuss CI artifacts on MRI, which are important for follow-up tumor recurrence. Thus, in future studies, we aim to investigate the long-term follow-up results and artifacts on MRI.

5 | CONCLUSION

In conclusion, simultaneous EETTA and CI are feasible for treating ILS and IAC fundus tumors. Preservation of the cochlear nerve and modiolus is important for favorable CI outcomes. Therefore, ILS and IAC fundus tumors in patients with nonserviceable hearing should be surgically removed as early as possible to enable proper hearing rehabilitation with CI.

ACKNOWLEDGMENTS

This study was supported by a faculty research grant from Yonsei University College of Medicine (6-2023-0088 to S.H.B.) and a National Research Foundation of Korea (NRF) grant funded by the Korean government (MSIT) (RS-2023-00253371 to I.S.M.).

CONFLICT OF INTEREST STATEMENT

All authors declare no conflict of interest.

ORCID

Seong Hoon Bae https://orcid.org/0000-0001-9243-9392
Ludovica Battilocchi https://orcid.org/0000-0003-0897-3264
Nam Yunbin https://orcid.org/0000-0002-6786-3666
Gerard Lapina https://orcid.org/0009-0003-2476-0063
Ji Min Yun https://orcid.org/0000-0002-7349-0472
In Seok Moon https://orcid.org/0000-0002-3951-5074

REFERENCES

1. Jackler RK, Pitts LH. Acoustic neuroma. *Neurosurg Clin N Am*. 1990; 1(1):199-223.
2. Tveiten OV, Carlson ML, Goplen F, Vassbotn F, Link MJ, Lund-Johansen M. Long-term auditory symptoms in patients with sporadic vestibular Schwannoma: an international cross-sectional study. *Neurosurgery*. 2015;77(2):218-227.
3. Graamans K, Van Dijk JE, Janssen LW. Hearing deterioration in patients with a non-growing vestibular schwannoma. *Acta Otolaryngol*. 2003;123(1):51-54.
4. Carlson ML, Jacob JT, Pollock BE, et al. Long-term hearing outcomes following stereotactic radiosurgery for vestibular schwannoma: patterns of hearing loss and variables influencing audiometric decline. *J Neurosurg*. 2013;118(3):579-587.
5. Holsinger FC, Coker NJ, Jenkins HA. Hearing preservation in conservation surgery for vestibular schwannoma. *Am J Otol*. 2000;21(5): 695-700.
6. Dhayalan D, Tveiten OV, Finnkirk M, et al. Upfront radiosurgery vs a wait-and-scan approach for small- or medium-sized vestibular Schwannoma: the V-REX randomized clinical trial. *JAMA*. 2023; 330(5):421-431.
7. Wick CC, Butler MJ, Yeager LH, et al. Cochlear implant outcomes following vestibular Schwannoma resection: systematic review. *Otol Neurotol*. 2020;41(9):1190-1197.
8. Goldbrunner R, Weller M, Regis J, et al. EANO guideline on the diagnosis and treatment of vestibular schwannoma. *Neuro Oncol*. 2020; 22(1):31-45.
9. Olson JJ, Kalkanis SN, Ryken TC. Congress of Neurological Surgeons systematic review and evidence-based guidelines on the treatment of adults with vestibular Schwannomas: executive summary. *Neurosurgery*. 2018;82(2):129-134.
10. Wick CC, Arnaoutakis D, Barnett SL, Rivas A, Isaacson B. Endoscopic Transcanal Transpromontorial approach for vestibular Schwannoma resection: a case series. *Otol Neurotol*. 2017;38(10):e490-e494.
11. Marchioni D, Alicandri-Ciufelli M, Rubini A, Masotto B, Pavesi G, Presutti L. Exclusive endoscopic transcanal transpromontorial approach: a new perspective for internal auditory canal vestibular schwannoma treatment. *J Neurosurg*. 2017;126(1):98-105.
12. Yong RL, Westerberg BD, Dong C, Akagami R. Length of tumor-cochlear nerve contact and hearing outcome after surgery for vestibular schwannoma. *J Neurosurg*. 2008;108(1):105-110.
13. Umezu H, Aiba T. Preservation of hearing after surgery for acoustic Schwannomas – correlation between Cochlear nerve function and operative findings. *J Neurosurg*. 1994;80(5):844-848.
14. Bae SH, Jung Y, Hur JH, Kim JH, Choi JY. Feasibility of speech testing using wireless connection in single-sided Cochlear implant users. *J Audiol Otol*. 2023;27(3):133-138.
15. Misron K, Mfuko G, Hur YK, Moon IS. Simultaneous Nonmastoidectomy Infrapromontorial tumor removal and Cochlear implantation in vestibular Schwannoma patient. *Otol Neurotol*. 2021;42(5):e631-e634.
16. Ma AK, Patel N. Endoscope-assisted partial Cochlectomy for Intracochlear Schwannoma with simultaneous Cochlear implantation: a case report. *Otol Neurotol*. 2020;41(3):334-338.
17. Carlson ML, Neff BA, Sladen DP, Link MJ, Driscoll CL. Cochlear implantation in patients with Intracochlear and Intralabyrinthine Schwannomas. *Otol Neurotol*. 2016;37(6):647-653.
18. Plontke SK, Rahne T, Pfister M, et al. Intralabyrinthine schwannomas: surgical management and hearing rehabilitation with cochlear implants. German version. *HNO*. 2017;65(5):419-433.
19. Häussler SM, Szczepek AJ, Gräbel S, Olze H. Challenges of Cochlear implantation in Intralabyrinthine Schwannoma patients: surgical procedures and auditory outcome. Journal of. *Clin Med*. 2021;10(17): 3899.
20. Plontke SK. An improved technique of subtotal Cochleoectomy for removal of Intracochlear Schwannoma and single-stage Cochlear implantation. *Otol Neurotol*. 2020;41(7):e891.
21. Plontke SK, Kösling S, Rahne T. Cochlear implantation after partial or subtotal Cochleoectomy for Intracochlear Schwannoma RemovalA technical report. *Otol Neurotol*. 2018;39(3):365-371.
22. Sudhoff H, Scholtz LU, Gehl HB, Todt I. Quality control after Intracochlear Intralabyrinthine Schwannoma resection and Cochlear implantation. *Brain Sci*. 2021;11(9):1221.
23. Laborai A, Ghiselli S, Cuda D. Cochlear implant in patients with Intralabyrinthine Schwannoma without tumor removal. *Audiol Res*. 2022; 12(1):33-41.
24. Marchioni D, De Rossi S, Soloperto D, Presutti L, Sacchetto L, Rubini A. Intralabyrinthine schwannomas: a new surgical treatment. *Eur Arch Otorhinolaryngol*. 2018;275(5):1095-1102.
25. Wu JF, Sun HJ, Chen BJ, Yuan YS, Wang WQ, Ren DD. Full endoscopic resection of Intralabyrinthine Schwannomas: a case series. *Ear Nose Throat J*. 2023;014556132311761. doi:10.1177/01455613231176170
26. Raza-Knight S, Chiuta S, Golash A, Gurusinghe N, Roberts G, Alalade AF. The role of endoscopy in the resection of sporadic vestibular Schwannomas: a systematic review of surgical outcomes. *Otol Neurotol*. 2022;43(1):2-11.
27. Presutti L, Magnaguagno F, Pavesi G, et al. Combined endoscopic-microscopic approach for vestibular schwannoma removal: outcomes in a cohort of 81 patients. *Acta Otorhinolaryngol Ital*. 2014;34(6): 427-433.
28. Choi JE, Jang JY, Cho YS. Cochlear implantation using a suprameatal approach in a case of severely contracted mastoid cavity. *Korean J Audiol*. 2014;18(3):144-147.
29. Kronenberg J, Migirov L, Dagan T. Suprameatal approach: new surgical approach for cochlear implantation. *J Laryngol Otol*. 2001;115(4): 283-285.
30. Kronenberg J, Baumgartner W, Migirov L, Dagan T, Hildesheimer M. The suprameatal approach: an alternative surgical approach to cochlear implantation. *Otol Neurotol*. 2004;25(1):41-45.
31. Postelmans JT, Tange RA, Stokroos RJ, Grolman W. The suprameatal approach: a safe alternative surgical technique for cochlear implantation. *Otol Neurotol*. 2010;31(2):196-203.
32. Tieleman A, Casselman JW, Somers T, et al. Imaging of intralabyrinthine schwannomas: a retrospective study of 52 cases with emphasis on lesion growth. *AJNR Am J Neuroradiol*. 2008;29(5):898-905.
33. Massager N, Drogba L, Delbrouck C, Benmebarek N, Desmedt F, Devriendt D. Gamma knife radiosurgery for intralabyrinthine schwannomas. *J Radiosurg SBRT*. 2011;1(3):237-245.
34. Tuleasca C, George M, Schiappacasse L, et al. Gamma knife radiosurgery for intravestibular and intracochlear schwannomas. *Acta Neurochir*. 2019;161(1):63-67.

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Bae SH, Battilocchi L, Yunbin N, Lapina G, Yun JM, Moon IS. Simultaneous cochlear implantation with early endoscopic surgery in small acoustic neuroma. *Laryngoscope Investigative Otolaryngology*. 2024;9(4): e1319. doi:10.1002/lio2.1319