Title

Cochlear Ossification After Vestibular Schwannoma Surgery: A Temporal Bone Study.

Journal
Otolaryngology - Head and Neck Surgery, 169(2)

Authors
Itamura, Kyohei
Geerardyn, Alexander
Podury, Archana
et al.

Publication Date
2023-08-01

DOI
10.1002/ohn.247

Peer reviewed

Published in final edited form as:
Otolaryngol Head Neck Surg. 2023 August ; 169(2): 333–339. doi:10.1002/ohn.247.

Cochlear Ossification After Vestibular Schwannoma Surgery: A Temporal Bone Study

Kyohei Itamura, MD[1], **Alexander Geerardyn, MD**[2,3], **Archana Podury, BA**[2], **Ivan A. Lopez, PhD**[4], **Yu-Tung Wong, MD**[1], **Akira Ishiyama, MD**[4], **Alicia M. Quesnel, MD**[2], **Mia E. Miller, MD**[1]

[1]Division of Otolaryngology–Head and Neck Surgery, Cedars-Sinai Medical Center, Los Angeles, California, USA

[2]Department of Otolaryngology–Head and Neck Surgery, Massachusetts Eye and Ear, Harvard Medical School, Boston, Massachusetts, USA

[3]Department of Neurosciences (ExpORL), KU Leuven, Leuven, Belgium

[4]Department of Otolaryngology–Head and Neck Surgery, University of California Los Angeles, Los Angeles, California, USA

Abstract

Objective.—This study aims to investigate patterns of cochlear ossification (CO) in cadaveric temporal bones of patients who underwent vestibular schwannoma (VS) surgery via the translabyrinthine (TL), middle cranial fossa (MF), or retrosigmoid (RS) approaches.

Study Design.—Histopathologic analysis of cadaveric temporal bones.

Setting.—Multi-institutional national temporal bone repository.

Methods.—The National Institute of Deafness and Communication Disorders and House Temporal Bone Laboratory at the University of California, Los Angeles and the Massachusetts Eye and Ear Otopathology Laboratory were searched for cadaveric temporal bones with a history of VS for which microsurgery was performed. Exclusion criteria included non-VS and perioperative death within 30 days of surgery. Temporal bones were analyzed histologically for CO of the basal, middle, and apical turns.

Results.—Of 92 temporal bones with a history of schwannoma from both databases, 12 of these cases met the inclusion criteria. The approaches for tumor excision included 2 MF, 4 RS, and 6 TL approaches. CO was observed in all temporal bones that had undergone TL surgery. Among

Corresponding Author: Kyohei Itamura, MD, Division of Otolaryngology–Head and Neck Surgery, Cedars-Sinai Medical Center, 8635 W 3rd Street, Suite 590W, Los Angeles, CA 90048, USA. kyohei.itamura@cshs.org.

Author Contributions

Kyohei Itamura, design, conduct, analysis, writing; **Alexander Geerardyn**, design, conduct, analysis, writing; **Archana Podury**, design, conduct, analysis, writing; **Ivan A. Lopez**, design, conduct, analysis, resources, writing; **Yu-Tung Wong**, design, analysis, writing; **Akira Ishiyama**, design, resources; **Alicia M. Quesnel**, design, conduct, analysis, resources, writing; **Mia E. Miller**, design, conduct, analysis, resources, writing.

Competing interests: Alicia M. Quesnel, MD, Grace Medical—sponsored research agreement, Frequency Therapeutics—sponsored research agreement, consulting, Alcon—consulting. Other authors declare no conflict of interest.

This article was presented at the 2022 AAO-HNSF Annual Meeting & OTO Experience; September 10-14, 2022; Philadelphia, Pennsylvania.

temporal bones that had undergone MF or RS surgeries, 5/6 had no CO, and 1/6 had partial ossification. This single case was noted to have intraoperative vestibular violation after RS surgery upon histopathologic and chart review.

Conclusion.—In this temporal bone series, all temporal bones that had undergone TL demonstrated varying degrees of CO on histological analysis. MF and RS cases did not exhibit CO except in the case of vestibular violation. When cochlear implantation is planned or possible after VS surgery, surgeons may consider using a surgical approach that does not violate the labyrinth.

Keywords

cochlear ossification; histopathology; temporal bone; vestibular schwannoma

---

Cochlear ossification (CO) is a known sequela of various otologic disease processes, including temporal bone trauma, infection, and autoimmune disorders.[1] Temporal bone surgery is another factor that has been shown to be associated with bony deposition within the cochlea. With regard to surgery for vestibular schwannoma (VS), 3 main approaches exist, the retrosigmoid (RS), middle cranial fossa (MF), and translabyrinthine (TL) approaches. These approaches can be generally divided into hearing-preserving versus nonpreserving techniques. As the only hearing nonpreserving technique, the TL approach disturbs the endolymph and perilymph most directly due to direct violation of the labyrinth. This labyrinthine violation can initiate a proinflammatory state and lead to intralabyrinthine osteoneogenesis.[2] Several radiologic studies have demonstrated evidence of extensive CO in follow-up T2-weighted magnetic resonance imaging (MRI) after TL surgery.[3–5] Hearing preservation techniques, however, do not necessarily disrupt the labyrinth.

Cochlear implantation (CI) has been recently used for hearing rehabilitation after VS excision in cases with an intact cochlear nerve.[6] In cases with hearing loss after VS surgery, hearing rehabilitation via CI may be affected by the presence of intracochlear inflammatory tissue or bone. CO may increase the difficulty of implantation and the risk for intraoperative complications, including inaccurate insertion and damage to adjacent structures due to loss of surgical landmarks.[7] Although modifications in technique for implanting an ossified cochlea have allowed for successful audiologic outcomes, there is a need to further characterize the histologic level patterns of CO after VS surgery to guide postoperative hearing-related management.

The main objective of this study is to investigate and compare patterns of CO in cadaveric temporal bones of patients who underwent VS surgery via the RS, MF, and TL approaches.

Methods

Identification of Cadaveric Temporal Bones

The National Institute of Deafness and Communication Disorders, National Temporal Bone House Institute Resource Registry, and the Massachusetts Eye and Ear (MEE) Otopathology Laboratory collection were searched for case records of temporal bones that contained “schwannoma” in the case summary after obtaining Institutional Review Board (IRB) approval (Mass General Brigham IRB #10–001449; University of California Los Angeles

IRB #10–001449). This search resulted in 49 samples in the MEE collection and 43 in the House collection. The case reports of each of these samples were analyzed in further detail.

Inclusion criteria were at least 18 years of age and a history of VS surgery. Exclusion criteria were neurofibromatosis type 2 and perioperative death within 30 days of surgery. Ultimately, 4 MEE and 8 HEI cases were selected after meeting the criteria.

Histopathologic Preparation and Analysis

The postmortem fixation time ranged from 1.5 to 28 h. After fixation in formalin, the specimens were decalcified in ethylenediamine tetra-acetic acid, followed by dehydration in alcohols and embedment in celloidin. Finally, the celloidin block containing the specimen was serially sectioned in the horizontal plane at a thickness of 20 μm. One in every 10 sections was stained with hematoxylin and eosin (H&E), and mounted for histologic examination as described by Merchant et al.[8] H&E sections of the cochlea were evaluated for the presence of bone, osteoid, fibrous tissue, and acidophilic precipitate in the scala tympani, vestibuli, and media at the basal, middle, and apical turns. The vestibule and semicircular canals were assessed for surgical damage.

Clinical Data Collection

The following information was retrieved from the case records: patient gender, age at the time of surgery, premortem clinical diagnosis, the surgical approach for VS resection, intraoperative violation of the labyrinth, postoperative complications, the time between surgical removal of the VS and death, and cause of death.

Results

The initial database search yielded 92 total temporal bones with a history of schwannoma. After inclusion and exclusion criteria, 12 temporal bones were selected for analysis, including 4 samples from patients with a history of VS surgery via the RS approach, 2 via the MF approach, and 6 via the TL approach (Table 1). The time period between the date of surgery and the date of death varied from 41 days to 29 years. Cases of perioperative death defined as within 30 days after surgery were excluded from this study.

Cases 1 to 4 were from cases of VS surgery via an RS approach (Table 2). Histopathological analysis showed no ossification within the cochlea for cases 1, 3, and 4 (Figure 1). Case 2, however, demonstrated ossification primarily in the scala media at the basal turn. This case was noted to have an intraoperative violation of the vestibule in the operative report. The remaining RS cases were not noted to have labyrinthine violation.

Cases 5 and 6 were from cases of VS surgery via an MF approach. There was no evidence of CO in these samples (Figure 1). No intraoperative labyrinthine violation was noted in the respective operative reports.

Cases 7 to 12 were from cases of VS surgery via a TL approach. Due to the nature of the TL approach, all of these cases, by definition, violated the labyrinth. All TL samples demonstrated CO; however, the locations and extent of ossification varied between them

(Figure 2). Case 7 showed the most significant extent of ossification with near complete obliteration of the scala media, scala tympani, and scala vestibuli at the apical, middle, and basal turns. Among the 7 total samples exhibiting CO, 3 cases had bone formation in all 3 cochlear turns (Table 3). All cases exhibited bone deposition at the basal turn. Complete ossification of at least 1 cochlear turn was seen in cases 7 and 9. The time interval between VS surgery and death within the ossified cohort ranged from 1.2 to 28 years.

Besides bone formation, other histopathological markers of chronic inflammation and osteoneogenesis were examined, including osteoid deposition, fibrous tissue, and acidophilic precipitate formation within the cochlea (Figure 3). All 3 markers were present in the cochlea in TL temporal bones. Of note, case 1, an RS temporal bone without labyrinthine violation, exhibited extensive fibrous tissue deposition throughout the entire cochlea. The acidophilic precipitate was present to varying extents in all samples except for case 5, an MF case without labyrinthine violation. The other MF temporal bone, case 6, also had no labyrinthine violation however did exhibit acidophilic precipitation.

Postoperative complications from available medical records were also reviewed. Cases 4, 5, and 11 had revision surgery within 30 days postoperatively for intracranial hemorrhage (case 4) and CSF leak (cases 5 and 11), respectively. There were no reports of postoperative meningitis. The causes of death of all patients were deemed to be unrelated to the tumor or surgery.

Discussion

CO is a known sequela that can occur in the setting of temporal bone surgery, trauma, autoimmune disease, or infectious processes, including chronic otomastoiditis, meningitis, and labyrinthitis.[1] Postmeningitic neoossification has been extensively studied. It involves an acute phase with infiltration of inflammatory mediators into the perilymph followed by stages of fibrous deposition and, ultimately, mineralization of osteoid into bone.[9] Obliteration of the intracochlear space by any etiology has considerable implications on hearing recovery and any subsequent efforts for hearing rehabilitation.[10,11] CO after surgery for VS, specifically, has been described in the radiologic literature and is an important consideration for patients in whom postoperative CI is being considered.

In the present histopathology study, temporal bone samples from 12 individual patients with a history of VS surgery were analyzed for CO. Four cases were via the RS approach, 2 via the MF approach and 6 via the TL approach. All TL samples exhibited varying degrees of CO at various locations within the cochlea, most commonly at the basal turn, without a particular predilection for endolymph versus perilymph. Animal and human models have shown that fibrosis and ossification after bacterial meningitis tend to start most at the area of the round window in the scala tympani via infiltration of proinflammatory cytokines through the cochlear aqueduct and progress from the basal turn[12] The pattern of ossification seen after TL surgery may reflect this pattern as the basal turn was involved in all ossified samples. Only one case from the RS or MF samples showed ossification. This particular case was clearly noted to have had an intraoperative violation of the vestibule in the operative report.

In addition to bone deposition, all TL samples exhibited osteoid and fibrous tissue formation, consistent with a picture of osteoneogenesis. Conversely, all samples without ossification did not have evidence of osteoid or fibrous tissue formation, except for one notable RS case in which fibrous tissue was found throughout the entire cochlea. As there was no gross labyrinthine violation noted in the operative report or microscopically in this particular case, the reason for this finding is unclear. The acidophilic precipitate was seen in 11 out of 12 total cases in the present study regardless of CO. This finding aligns with a previous histopathologic study describing the deposition of these precipitates in the cochlear endolymph and perilymph in temporal bones of patients with untreated VS.[13] There has been radiographic correlation of increased intracochlear protein deposition in patients with VS fluid-attenuated inversion recovery signal compared to age-matched controls.[14] This phenomenon has been postulated to be related to local cytokine production due to the tumor or compromise of the cochlear vascular supply, resulting in a higher overall protein concentration in the perilympathic milieu.[15,16] However, there has been no strong evidence correlating VS tumor size, location, or nerve origin to the extent of cochlear pathology.

The present study expands upon a prior temporal bone histopathology study which demonstrated progressive cochlear osteoneogenesis after TL surgery and after MF surgery for VS removal, after which hearing preservation was not achieved.[17] These histologic changes were attributed to ischemia from vascular compromise induced by the surgery itself. In the current study, we demonstrate that hearing preservation approaches without labyrinthine violation may have lower rates of osteoneogenesis within the cochlea.

Varying degrees of cochlear obliteration has been seen on follow-up MRI after VS microsurgery. Hedjrat et al[18] retrospectively reviewed 65 patients after RS VS surgery and found a third of their cohort had evidence of CO on postoperative MRI at a median follow-up time of 28 months. This finding was corroborated by Grenness et al[19] who showed that 68% of their VS cohort who underwent the RS approach had no inner ear fluid MRI signal abnormalities on follow-up. Shapiro et al[20] in their study of 51 patients who underwent the MF approach, observed that in those with preserved hearing with MRI at least 1 year after surgery, 25% had evidence of CO on MRI. Of note, these studies do not contain specific detail regarding the intraoperative labyrinthine violation. Hearing preservation surgery, thus, for VS appears to be associated with postoperative CO in only a minority of patients. In contrast, studies of the TL approach have noted a significant rate of loss of cochlear patency postoperatively. In one study with 41 post-TL patients for VS removal, at the first postoperative MRI, 78% of the cohort had some degree of CO.[3] Carswell et al[4] found loss of cochlear patency in 73% of their post-TL patients after 1 year after surgery. These studies do demonstrate gross cochlear obliteration on imaging, however, the present study further shows that differing degrees of cochlear fibrosis and ossification may be present at the microscopic level.

Several studies have directly compared postoperative CO after the different VS surgery approaches using MRI. Feng et al[5] examined basal turn obliteration on first and last follow-up MRIs of patients who had undergone VS surgery via TL, MF, or RS approaches, respectively. Compared to MF and RS approaches, the TL approach conferred the highest rate of partial obstruction at the first follow-up and of complete obstruction at the last follow-up MRI. These findings were further supported by van Waegeningh et al[21] who compared cochlear patency via postoperative MRI scans of TL versus RS cases and found that 84% versus 20%, respectively, had partial or complete basal or apical turn obstruction by a mean postoperative interval of 127 and 140 days.

Postoperative CO is important for patients who are considering CI after surgery for VS. In the past, cochlear obliteration was deemed a relative contraindication to CI due to increased theoretical risk of electrode misplacement or damage to the facial nerve.[22] Modifications to implantation technique, however, have increasingly allowed successful implantation with acceptable long-term audiometric outcomes.[23,24] These techniques include using image guidance to help with the loss of surgical landmarks during basal turn drill out, implanting stiffer dummy electrodes to overcome resistance during insertion where fibrous tissue is encountered, and opting for a shorter double-array implant.[25] Studies of postmeningitis CI have also postulated the ideal timing of implantation to be before ossification sets in, which may occur as early as 21 days postinfection.[2,26] In a retrospective review of 126 patients with profound hearing loss after meningitis, Durisin et al[2] showed that cochlear osteoneogenesis can be detected as early as 1-month postinfection and increases significantly over time at an unpredictable rate.

CO that occurs after CI placement may also have implications on implant function, including increased impedances and difficulty programming the implant.[27] Postoperative aberrant facial nerve stimulation has also been associated with CI in the setting of CO.[28,29] A retrospective study by Smullen et al[30] described 2 patients out of 39 total patients who had postimplantation facial nerve stimulation. These patients had completely ossified cochleas and required drill-out and partial electrode insertion.

CO after temporal bone surgery had also been managed by implanting a placeholder electrode or simultaneous implantation to place the CI electrode before CO begins. Hassepass et al[6] in their study implanted a placeholder electrode at the time of TL surgery in 11 patients and later implanted a true electrode 1 year postoperatively after confirming no tumor recurrence and an electrically responsive cochlea with promontory stimulation in 4 patients. Significant benefits to hearing and tinnitus suppression were observed in their experience.[6] Others have shown the feasibility of simultaneous TL surgery with CI to avoid a second-stage procedure in highly selective cases.[31] However, management of hearing loss after VS surgery remains surgeon-dependent. Based on the present study, the extent of ossification after TL surgery is highly variable, even 10 to 20 years postoperatively. This observation may provide an argument for a placeholder electrode at the time of TL surgery to assure cochlear patency down the road, as the extent of ossification is not predictable.

The main limitation of this study is the ability to examine only one time point after surgery given the nature of human temporal bone studies and the small sample size, which precludes any statistical inference. Qualitative assessments of the degree of osteoneogenesis were used because there were not enough cases to make a comparison with finer volumetric analysis useful. Furthermore, the variable availability of medical records prevented a complete review of other possible factors in the patient’s history that may have influenced CO.

Conclusions

The TL approach to VS surgery is associated with varying degrees of ossification of the ipsilateral cochlea. Hearing preservation approaches, including RS and MF approach, did not exhibit ossification in the current study, except in the case of known intraoperative violation of the vestibule. CO may have clinical implications for subsequent CI.

Funding source:

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: National Institute on Deafness and Communication Disorders (Grant Numbers U24-DC013983-06, U24-DC15910).

References

1. Buch K, Baylosis B, Fujita A, et al. Etiology-specific mineralization patterns in patients with labyrinthitis ossificans. AJNR Am J Neuroradiol. 2019;40(3):551–557. [PubMed: 30792250]
2. Durisin M, Bartling S, Arnoldner C, et al. Cochlear osteoneogenesis after meningitis in cochlear implant patients: a retrospective analysis. Otol Neurotol. 2010;31(7): 1072–1078. [PubMed: 20812396]
3. Delgado-Vargas B, Medina M, Polo R, et al. Cochlear obliteration following a translabyrinthine approach and its implications in cochlear implantation. Acta Otorhinolaryngol Ital. 2018;38(1):56–60. [PubMed: 29187758]
4. Carswell V, Crowther JA, Locke R, Taylor W, Kontorinis G. Cochlear patency following translabyrinthine vestibular schwannoma resection: implications for hearing rehabilitation. J Laryngol Otol. 2019;133(7):560–565. [PubMed: 31267888]
5. Feng Y, Lane JI, Lohse CM, Carlson ML. Pattern of cochlear obliteration after vestibular schwannoma resection according to surgical approach. Laryngoscope. 2020;130(2): 474–481. [PubMed: 30919457]
6. Hassepass F, Arndt S, Aschendorff A, Laszig R, Wesarg T. Cochlear implantation for hearing rehabilitation in single-sided deafness after translabyrinthine vestibular schwannoma surgery. Eur Arch Otrhinolaryngol. 2016; 273(9):2373–2383.
7. Singhal K, Singhal J, Muzaffar J, Monksfield P, Bance M. Outcomes of cochlear implantation in patients with postmeningitis deafness: a systematic review and narrative synthesis. J Int Adv Otol. 2020;16(3):395–410. [PubMed: 33136024]
8. Merchant SN, Nadol JB. Schuknecht's Pathology of the Ear. PMPH-USA; 2010.
9. Paparella MM, Sugiura S. The pathology of suppurative labyrinthitis. Ann Otol Rhinol Laryngol. 1967;76(3):554–586. doi:10.1177/000348946707600303 [PubMed: 4963157]
10. Dodge PR, Davis H, Feigin RD, et al. Prospective evaluation of hearing impairment as a sequela of acute bacterial meningitis. N Engl J Med. 1984;311(14): 869–874. [PubMed: 6472398]
11. Novak MA, Fifer RC, Barkmeier JC, Firszt JB. Labyrinthine ossification after meningitis: its implications for cochlear implantation. Otolaryngol Head Neck Surg. 1990;103(3):351–356. [PubMed: 2122362]
12. Trakimas DR, Knoll RM, Castillo-Bustamante M, Kozin ED, Remenschneider AK. Otopathologic analysis of patterns of postmeningitis labyrinthitis ossificans. Otolaryngol Head Neck Surg. 2021;164(1):175–181. [PubMed: 32600100]
13. Roosli C, Linthicum FH Jr, Cureoglu S, Merchant SN. Dysfunction of the cochlea contributing to hearing loss in acoustic neuromas: an underappreciated entity. Otol Neurotol. 2012;33(3):473–480. [PubMed: 22377650]
14. Bhadelia RA, Tedesco KL, Hwang S, et al. Increased cochlear fluid-attenuated inversion recovery signal in patients with vestibular schwannoma. AJNR Am J Neuroradiol. 2008;29(4): 720–723. [PubMed: 18238842]

15. Silverstein H Labyrinthine tap as a diagnostic test for acoustic neurinoma. Otolaryngol Clin North Am. 1973; 6(1):229–244. [PubMed: 4220279]
16. Lysaght AC, Kao SY, Paulo JA, Merchant SN, Steen H, Stankovic KM. Proteome of human perilymph. J Proteome Res. 2011;10(9):3845–3851. [PubMed: 21740021]
17. Belal A Is cochlear implantation possible after acoustic tumor removal? Otol Neurotol. 2001;22(4):497–500. [PubMed: 11449107]
18. Hedjrat A, Schwager K, Hofmann E, Behr R. Postoperative cochlear obliteration after retrosigmoid approach in patients with vestibular schwannoma. J Neurol Surg B Skull Base. 2018;79(4):343–348. [PubMed: 30009114]
19. Grenness A, Hill FCE, Withers S, Iseli C, Briggs R. Inner ear patency after retrosigmoid vestibular schwannoma resection. Aust J Otolaryngol. 2018;1:26. doi:10.21037/ajo.2018.09.07
20. Shapiro SB, Kemper N, Jameson A, et al. Cochlear ossification after vestibular schwannoma resection via the middle cranial fossa approach. J Neurol Surg B Skull Base. 2021;82:S65–S270. doi:10.1055/s-0041-1725564 [PubMed: 36338786]
21. van Waegeningh HF, Loos E, Havenbergh TV, Somers T. Cochlear patency after translabyrinthine and retrosigmoid vestibular schwannoma surgery. J Int Adv Otol. 2020; 16(1):53–57. [PubMed: 32401202]
22. Balkany T, Bird PA, Hodges AV, Luntz M, Telischi FF, Buchman C. Surgical technique for implantation of the totally ossified cochlea. Laryngoscope. 1998;108(7):988–992. [PubMed: 9665244]
23. Vashishth A, Fulcheri A, Prasad SC, et al. Cochlear implantation in cochlear ossification: retrospective review of etiologies, surgical considerations, and auditory outcomes. Otol Neurotol. 2018;39(1):17–28. [PubMed: 29065093]
24. Wanna GB, Carlson ML, Blachon GS, et al. Implantation of the completely ossified cochlea: an image-guided approach. Otol Neurotol. 2013;34(3):522–525. [PubMed: 23370556]
25. Eshraghi AA, Ocak E. Cochlear implant electrode choice in challenging surgical cases: malformation, residual hearing, ossification, or reimplantation. Curr Otorhinolaryngol Rep. 2017;5(4):315–322. doi:10.1007/s40136-017-0171-3
26. Parisier SC, Chute PM. Multichannel implants in postmeningitic ossified cochleas. Adv Otorhinolaryngol. 1993;48: 49–58. [PubMed: 8273499]
27. Foggia MJ, Quevedo RV, Hansen MR. Intracochlear fibrosis and the foreign body response to cochlear implant biomaterials. Laryngoscope Investig Otolaryngol. 2019;4(6): 678–683.
28. Niparko JK, Oviatt DL, Coker NJ, Sutton L, Waltzman SB, Cohen NL. Facial nerve stimulation with cochlear implantation. Otolaryngol Head Neck Surg. 1991;104(6):826–830. doi:10.1177/019459989110400610 [PubMed: 1908975]
29. Muckle RP, Levine SC. Facial nerve stimulation produced by cochlear implants in patients with cochlear otosclerosis. Am J Otol. 1994;15(3):394–398. [PubMed: 8579147]
30. Smullen JL, Polak M, Hodges AV, Payne SB, Telischi FF, Balkany TJ. Facial nerve stimulation after cochlear implantation. Laryngoscope. 2005;115(6):977–982. doi:10.1097/01.mlg.0000163100.37713.c6 [PubMed: 15933504]
31. Dos Santos Neto PH, Zamponi JO, Hamerschmidt R, Wiemes GRM, Rassi MS, Borba LAB. Simultaneous cochlear implantation as a therapeutic option in vestibular schwannoma surgery: case report. Neurosurg Focus. 2018;44(3):E9.

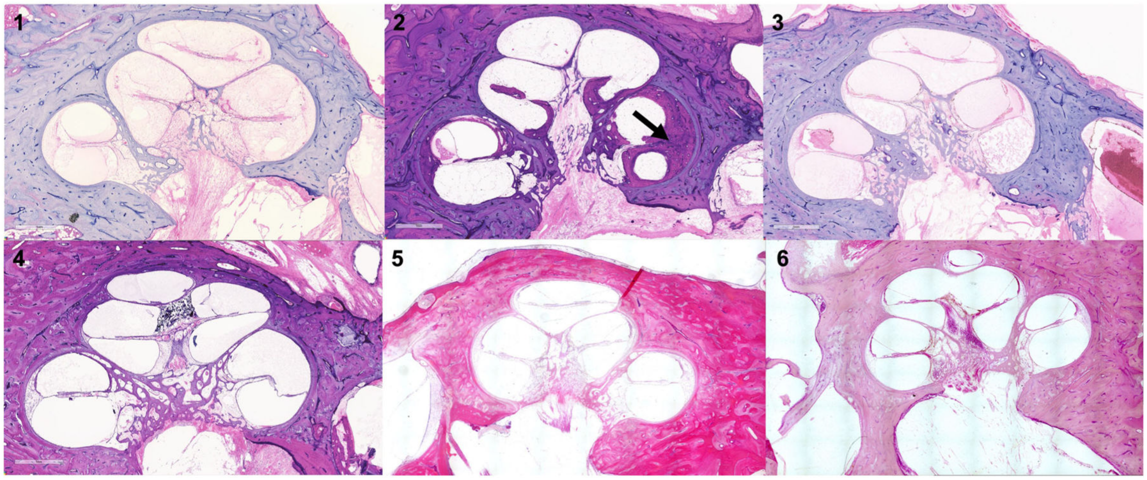

Figure 1.
Histopathology of the cochlea from temporal bone of patients with a history of vestibular schwannoma surgery via retrosigmoid (cases 1–4) and middle cranial fossa (cases 5–6) approach. Black arrows denote areas of ossification.

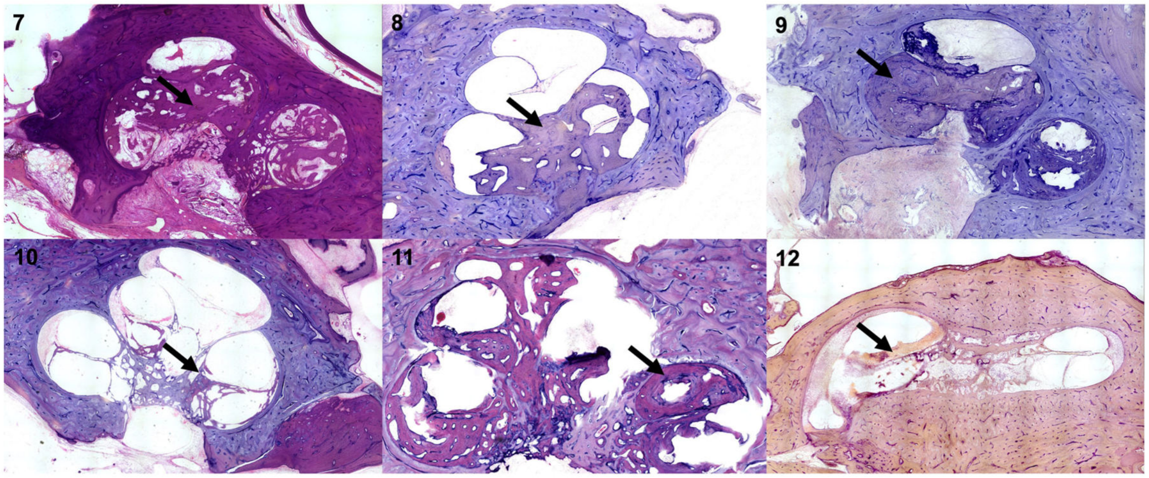

Figure 2.

Histopathology of the cochlea from temporal bone of patients with a history of vestibular schwannoma surgery via translabyrinthine (cases 7–12) approach. Black arrows denote areas of ossification.

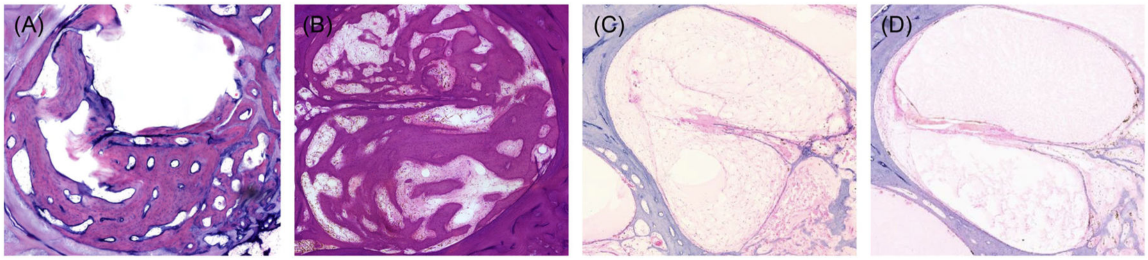

Figure 3.

Magnified view of (A) intracochlear bone, (B) osteoid, (C) fibrous tissue, and (D) acidophilic precipitate formation.

Table 1.

Basic Patient and Surgical Characteristics of the Temporal Bone Cohort

Case	Age at surgery	Gender	Time from surgery to death (y)	Laterality	Approach	Postoperative complications
1	76	F	0.11	R	RS	None
2	67	M	1.2	R	RS	None
3	47	F	22	R	RS	None
4	58	F	25	R	RS	Surgical site hemorrhage
5	68	F	29	R	MF	None
6	61	F	11	R	MF	None
7	48	F	14	R	TL	None
8	67	F	25	L	TL	None
9	69	M	18	L	TL	None
10	67	F	23	L	TL	None
11	67	F	28	R	TL	Surgical site CSF leak
12	66	M	11	L	TL	Surgical site CSF leak

Abbreviations: CSF, cerebrospinal fluid; F, female; L, left; M, male; MF, middle cranial fossa; R, right; RS, retrosigmoid; TL, translabyrinthine.

Table 2.

Presence (+ = any, − = none) of Bone, Osteoid, Fibrous Tissue, and Acidophilic Precipitate Formation in the ST, SV, and SM

			Bone			Osteoid			Fibrous tissue			
Case	**Approach**	**Intraoperative labyrinth violation**	**ST**	**SV**	**SM**	**ST**	**SV**	**SM**	**ST**	**SV**	**SM**	**Acidophilic precipitate**
1	RS	−	−	−	−	−	−	−	+	+	+	+
2	RS	+	+	+	+	+	+	−	+	+	−	+
3	RS	−	−	−	−	−	−	−	−	−	−	+
4	RS	−	−	−	−	−	−	−	−	−	−	+
5	MF	−	−	−	−	−	−	−	−	−	−	−
6	MF	−	−	−	−	−	−	−	−	−	−	+
7	TL	+	+	+	+	+	+	+	+	+	+	+
8	TL	+	+	+	+	+	+	+	+	+	+	+
9	TL	+	+	+	+	+	+	+	+	+	+	+
10	TL	+	+	+	+	+	−	−	+	−	−	+
11	TL	+	+	+	+	+	+	+	+	+	+	+
12	TL	+	+	+	+	+	+	+	+	+	+	+

Abbreviations: MF, middle cranial fossa; RS, retrosigmoid; SM, scala media; ST, scala tympani; SV, scala vestibuli; TL, translabyrinthine.

Table 3.

Location (Basal, Middle, Apical Turn) and Extent (+++ = 75%–100%, ++ = 25%–75%, + = <25%, − = None) of Intracochlear Bone Formation in Samples With Cochlear Ossification

Case	Basal turn	Middle turn	Apical turn
2	++	+	−
7	+++	+++	+
8	++	−	−
9	++	+++	+
10	+	+	−
11	++	++	+
12	+	+	−