Postoperative Cochlear Obliteration after Retrosigmoid Approach in Patients with Vestibular Schwannoma

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J Neurol Surg B 2018;79:343–348.

Abstract

Objective Vestibular schwannomas (VSNs) account for the vast majority of lesions located in the cerebellopontine angle (CPA). The goals of VSN surgery are possible total tumor removal, intact facial nerve function, and preservation of cochlear nerve function. In cases of pre- or postoperative deafness, restoration of hearing with auditory brainstem implant (ABI) or cochlear implant (CI) is a promising treatment option with normally better results in CI than in ABI. The aim of this retrospective study is to evaluate cochlear ossification or obliteration secondary to a retrosigmoid approach, which is important for later CI, especially in single-sided deafness.

Materials and Methods We retrospectively reviewed data from our suboccipital retrosigmoid operation database for the period from January 2008 to February 2015. A total of 65 patients with VSN could be analyzed retrospectively. The patient's data (age, gender, side of operation, tumor entities, and the duration of follow-up) were evaluated. The most recent T2-weighted MRI exams were taken into account for the evaluation of cochlea. To compare left and right sides, the coronal reformatted images were reconstructed in a symmetrical way.

Results Twenty-two out of 65 (33%) patients had cochlear obliteration in our survey. The cochlear obliteration was more common in females (44 vs. 20% in males). The median follow-up was 28 months. The size and the intrameatal extension of tumors could not be considered as factors influencing the cochlear obliteration rate.

According to our survey, 33% of suboccipital approaches manifested cochlear obliteration to some extent. It was more common in females. The intrameatal extension of tumors played statistically no role in the occurrence of postoperative cochlear obliteration. Whether the prohibition of cochlear ossification can be best achieved by retrosigmoid approaches, compared to other approaches to the CPA, or not could be a subject of future studies.

Keywords

- vestibular schwannoma
- CPA
- tumor
- cochlear obliteration
- DRIVE-sequence
- retrosigmoid approach
- cochlear ossification
- cochlear implant

received
April 26, 2017
accepted after revision
September 15, 2017
published online
November 20, 2017

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Stuttgart · New York

DOI <https://doi.org/10.1055/s-0037-1608649>.
ISSN 2193-6331.

Introduction

The vestibular schwannomas (VSNs) account for the vast majority of lesions located in cerebellopontine angle (CPA). The meningiomas and epidermoids are the next common lesions in this area. The goals of VSN surgery are intact facial nerve function, if possible preservation of cochlear nerve function, and total or near total tumor removal. There are three approaches in the treatment of VSNs, the retrosigmoid, translabyrinthine, and middle fossa approaches.

There exist a few studies focusing on the relation of VSN operations and cochlear ossification. Belal et al reported that it is possible to do cochlear implantation (CI) after acoustic tumor removal provided that the cochlear nerve is intact and the implantation is done at the time of acoustic tumor removal or shortly thereafter, before cochlear ossification is complete.¹ The middle fossa procedure is a hearing preserving approach. It allows complete exposure of the internal acoustic canal. Nevertheless, the risk of profound postoperative hearing loss exists.² In the study by Belal et al,¹ the patient with profound postoperative deafness showed severe degenerative changes and ossification in the membranous labyrinth. This was explained by the occlusion of internal auditory artery.¹ Warren et al described the T2-weighted magnetic resonance findings after hearing preservation surgery for acoustic tumor removal. Loss of inner ear signal on T2-weighted images correlates with loss of hearing postoperatively, whereas preserved inner ear signal correlates with hearing preservation after middle fossa surgery for VSN removal.³

In spite of continuously improving results in ABI implantations, CI is still a better technique for restoration of hearing, if the auditory nerve is preserved and if the cochlea is patent (Behr et al⁴ and Carlson et al⁵).

However, the success of a cochlear implantation in the presence of severe cochlear ossification is strongly restricted due to the technical challenges and histological factors.^{3,6–9} Beutner et al demonstrated the frequency of

labyrinthine obstruction as high as in 66.7% of patients and as early as 3 months after translabyrinthine approaches to VSN. Partial and complete cochlear obstructions could be observed in 22.2 and 33.3%, respectively, 1 year after the operation. This shows that cochlear changes occur early after translabyrinthine VSN resection.¹⁰ We decided to study the frequency of cochlear obliteration after retrosigmoid approach as one of the most common approaches to the CPA. Furthermore, we assessed the relation between the intracanalicular extension of VSN and the occurrence of cochlear obliteration.

Materials and Methods

We retrospectively reviewed data from our suboccipital retrosigmoid operation database for the period from January 2008 to February 2015. Besides standard microsurgical technique, operations were performed endoscopically assisted or even exclusively endoscopic in cooperation with our ENT department. After the extirpation of the extrameatal part of the tumor, the intrameatal tumor could be resected after unroofing the internal acoustic canal. The electrophysiological monitoring of cochlear and facial nerves was performed throughout the operation. We included only patients who underwent a postoperative T2-weighted MRI (DRIVE-sequence) to evaluate the cochlea on the side of the operation. The scans were performed by a 3 Tesla MRI scanner. The last available MRI study was taken into account in our survey. Only MR examinations with a submillimeter high-resolution dataset were used. The images were interactively reformatted in the exact coronal plane to enable us to make a perfect right–left match of the inner ear details. Thickness of the reformatted slice was 0.3 mm. To search for any obliteration, these reformations were manually scrolled symmetrically from the cochlear apex anteriorly to the most posterior extension of the posterior semicircular canal posteriorly (→ **Figs. 1** and **2**). Since the study was conducted retrospectively, there were no postoperative CT scans routinely.

Fig. 1 Two samples of pre- and postoperative MRI exams reveal a patent cochlea (right) and an obstructed one (left). MRI, magnetic resonance imaging.

Fig. 2 Reformatted coronal examination with detailed exposure of cochlea (coc), anterior semicircular canal (asc), inferior semicircular canal (isc), posterior semicircular canal (psc), and vestibulum (ves), obliteration of inner ear on the right side.

Obliteration was assumed if there was a reduction of signal or even a complete signal dropout in the corresponding structures (cochlea, vestibulum, and lateral, posterior, or anterior semicircular canals). In addition, the size and the location of

tumors, their relation to the fundus and internal acoustic canal were studied. The medical record was reviewed for histological diagnosis, gender, age of patients, and the side of operation. The duration of the follow-up was identified in addition to cochlear visibility on the basis of MRI examinations.

Results

We operated 84 patients with space-occupying lesions in CPA in our department from January 2008 to February 2015. Due to missing MRI control in the follow-up and some other diagnoses, such as meningioma, neurinoma, 18 patients were not eligible for the analysis. Furthermore, in one patient, cochlear ossification had already been identified in the preoperative MRI examinations. Therefore, 65 patients (36 females, 29 males, median age: 51 years) were available for analysis. The patient characteristics of remaining 65 patients are demonstrated in ▶Table 1.

The median follow-up was 28 months (range: 1–86 months). The evaluation of cochlear patency was only performed in patients undergoing an operative procedure directly at the

Table 1 Patients characteristics

No.	Age	Gender	Follow-up (mo)	Diagnosis	Cochlear obliteration	Side	Diameter (mm)	Location	Int (Canal or fundus)
1	65	F	65	VSN	No	L	29	Ext	
4	49	M	78	VSN	No	R	7	Int	C
5	74	M	61	VSN	No	L	39	Ext	
6	46	M	28	VSN	No	R	8	Int	C
9	71	F	19	VSN	No	R	30	Ext	
11	58	F	19	VSN	Yes	R	14	Ext	
12	75	M	44	VSN	No	L	7	Ext	
13	72	M	5	VSN	Yes	L	18	Ext/Int	C + F
14	21	M	65	NFII/ VSN	No,	L	32	Ext/Int	C + F
15	53	M	14	VSN	No	R	15	Ext/Int	C + F
16	42	F	60	VSN	No	R	15	Int	
17	64	F	29	VSN	No	L	16	Ext	
18	21	M	6	NFII/ VSN	No	L	13,5	Ext	
19	39	F	45	VSN	No	R	15,6	Ext	
20	69	F	78	VSN	No	R	8	Int	C + F
21	43	M	45	VSN	No	R	39	Ext	
22	21	M	69	NFII/ VSN	No,	L	37	Ext	
23	64	F	2	VSN	No	R	17	Int/Ext	C
24	34	F	59	VSN	Yes	R	30	Ext	
25	37	F	47	VSN	No	R	30	Ext	
26	43	F	37	VSN	Yes	L	18	Ext	
27	44	F	48	VSN	No	L	15	Ext	
28	56	M	60	VSN	No	L	24	Ext	
29	53	M	60	VSN	No	L	12	Ext	

(Continued)

Table 1 (Continued)

No.	Age	Gender	Follow-up (mo)	Diagnosis	Cochlear obliteration	Side	Diameter (mm)	Location	Int (Canal or fundus)
30	61	F	33	VSN	Yes	L	16	Ext	
31	78	F	56	VSN	No	L	10	Ext	
32	85	F	48	VSN	No	R	23	Ext	
33	62	M	30	VSN	No	L	8	Int	C
34	70	F	47	VSN	Yes	L	23	EXT/Int	C
35	50	M	53	VSN	No	R	16	Ext	
40	51	F	5	VSN	No	R	25	Ext	
41	60	F	36	VSN	No	L	19	Ext	
42	72	F	44	VSN	No	L	22	Ext	
43	37	M	38	VSN	Yes	L	19	Ext	
44	69	F	37	VSN	Yes	L	17	Ext	
45	32	M	40	VSN	No	R	12	Ext	
46	61	M	3	VSN	No	L	13	Ext	
47	24	M	36	NFII/ VSN	No,	L	38	Ext	
49	35	F	4	VSN	Yes	L	32	Ext	
50	42	M	11	VSN	No	L	28	Ext	
51	80	M	1	VSN	Yes	R	32	Ext	
52	43	F	9	NFII/ VSN	No	R	28	Ext/Int and temporal	C + F
53	71	F	21	VSN	Yes	L	15	Ext	
54	20	F	31	NFII/ VSN	Yes,	L	22	Ext	
56	53	F	26	VSN	Yes	L	14	Ext	
58	47	M	33	VSN	No	L	9	Ext	
61	49	M	27	VSN	No	L	33	Ext	
62	46	F	15	VSN	Yes	R	16	Ext	
63	26	M	7	VSN	No	R	26	Ext	
64	43	M	6	VSN	No	L	14	Ext	
65	78	F	2	VSN	No	L	12	Ext	
66	49	F	16	VSN	No	R	16	Int/Ext	C + F
67	63	F	18	VSN	Yes	L	14	Int	C + F
70	50	M	9	VSN	Yes	R	18	Ext/Int	C + F
71	72	M	13	VSN	Yes	R	32	Ext	
72	70	F	16	VSN	Yes	R	8	Ext	
73	52	M	12	VSN	Yes	L	19	Ext	
77	32	M	4	NFII/ VSN	No,	R	27	Ext/Int	C + F
78	58	F	4	VSN	No	R	16	Ext/Int	C + F
80	64	F	3	VSN	Yes	L	16	Ext/Int	C + F
81	35	F	4	VSN	No	R	34	Ext	
82	71	F	3	VSN	No	R	14	Int	C + F
83	35	M	2	VSN	No	L	39	Ext/Int	C + F
84	23	F	2	VSN	Yes	R	28	Ext	
87	33	F	86	VSN	Yes	L	15	Ext	

Abbreviations: C, internal acoustic canal location; Ext, extrameatal location; F, fundus location; F, female; Int, intrameatal location; M, male; NFII, neurofibromatosis type II; VSN, vestibular schwannoma.

petrous bone around the internal acoustic canal. We decided to improve the precision with reconstruction of thin-slice coronal examinations. The coronal reformatted images in absolutely symmetrical way enabled us to compare the left and right sides. The cochlear obliteration was also visible on source images but the peri- and endolymphatic fluid were more conspicuous in symmetrical images. There was no banding artifact in the DRIVE-sequence. In a total of 22 patients (33%), the cochlea could not be identified in the last follow-up control (► **Table 2**). The obliteration rate turned out to be higher in semicircular canals. The summary of the data is demonstrated in ► **Table 3**. According to our data, we could not find any propensity of the intrameatal or even fundal extension of tumors to a higher cochlear obliteration rate. Seventy percent of cochlear obliterations occurred in spite of the exclusively extrameatal location of tumors. To our surprise, the cochlear obliteration was more common in females (44 vs. 20% in males). The median age of patients with cochlear obliteration was 55.5 years, which was not significantly different from the whole studied cohort. The greatest measurable diameters on axial images were taken into account. We found no significant difference between the whole studied population and the subpopulation with cochlear obliteration on the basis of the tumor diameter (► **Table 3**).

Table 2 Patients with postoperative cochlear obliteration

Pat. no.	Follow-up (mo)	Tumor diagnosis	Gender	Age (y)
11	19	VSN	F	58
13	5	VSN	M	72
24	59	VSN	F	34
26	37	VSN	F	43
30	33	VSN	F	61
34	47	VSN	F	70
43	38	VSN	M	37
44	37	VSN	F	69
49	4	VSN	F	35
51	1	VSN	M	80
53	21	VSN	F	71
54	31	VSN/NFII	F	20
56	26	VSN	F	53
62	15	VSN	F	46
67	18	VSN	F	63
70	9	VSN	M	50
71	13	VSN	M	72
72	16	VSN	F	70
73	12	VSN	M	52
80	3	VSN	F	64
84	2	VSN	F	23
87	86	VSN	F	33

Abbreviations: F, female; M, male; NFII, neurofibromatosis type II; VSN, vestibular schwannoma.

Table 3 Data summary

Characteristics	Patients N (%)
Age (y)	
Median	51
Range	20–85
Gender	
Male	29 (45)
Female	36 (55)
Size (mm)	7–39
Median	23
Range	7–39
Follow-up interval (mo)	
Median	28
Range	1–86
Obliteration	
Cochlea	22 (33)
Lateral semicircular canal	38 (58)
Posterior semicircular canal	39 (60)
Anterior semicircular canal	37 (56)
Vestibulum	20 19 (29)
Cochlear obliteration	
Median age (y)	55.5
Female/male ratio	2.2
Median size and range (mm)	18 and 8–32
Exclusively extrameatal location	17 (77)

Discussion

Due to advancements both in implant technology and surgical implantation of cochlear implants, a cochlear nerve preserving approach has gained increasing interest in the surgical therapy of VSNs in bilateral or even unilateral lesions. According to the available publications, an ossified cochlea is an obstacle or at least a technical challenge in case of CI.^{3,6–9}

We have reviewed the related publications in PubMed in the past 32 years. There was no similar study to evaluate the effect of approaches to CPA to cause cochlear ossification to such an extent.^{1,8} In a few available studies, the T2-weighted MRI turned out to be a very accurate method to determine and predict cochlear obstruction in pediatric patients with meningitis.¹¹ Additionally, one study showed that there was no significant difference between early (0–3 months) and late (>3 months) scanning, showing that radiological imaging soon after meningitis allowed early diagnosis.¹² On the other hand, Beutner et al succeeded to demonstrate how early the cochlear changes could happen, even as early as 3 months, after tranlabrynthine approaches.¹⁰ In our study, the median follow-up was 28 months, which indicates that a CI is still possible after a long period after previous tumor operations. Patients, who failed to cope with unilateral deafness, still have the

opportunity to be treated with CI even years after the retrosigmoid operation. Furthermore, 43 patients (66%) showed no fibrosis after the retrosigmoid operations, which can still be an argument for this approach. Nevertheless, we found surprisingly high rate of fibrosis in inner ear after this approach. Cochlear obliteration could be observed in 22 patients (33%). Even higher fibrosis rates were determined in semicircular canals. Which factors could contribute to this phenomenon is still unclear. Perhaps the mechanical or thermal trauma, the compromise of blood supply, and even the inflammation can play a role. A banding artifact can be excluded, since no echogradient-based imaging was performed. The symmetrical presentation of the inner ear structures contributed merely to improve the conspicuity of obliteration. Hearing loss not only occurred suddenly during the course of operation in translabyrinthine procedure attributed to surgical trauma, but a decrease in hearing was also observed over time in the majority of patients after middle fossa or retrosigmoid approach with initial hearing preservation possibly due to loss of terminal blood supply via labyrinthine artery.¹⁰ Finally, instead of mono-dimensional measurement, an exact volumetric assessment of the size of the tumors can improve the precision of the survey in question of size obliteration correlation. In our opinion, the main key to prevent deafness is to prohibit ossification. Although we showed a relatively high rate of cochlear obliteration occurring after the retrosigmoid approaches in our study, we believe that retrosigmoid approaches are still safer compared to subtemporal and translabyrinthine ones. Whether the prohibition of cochlear ossification can be best achieved by retrosigmoid approach, compared to other approaches to the CPA or not, can be a subject of future studies.

Conclusion

Thirty-three percent of suboccipital retrosigmoid approaches manifested cochlear obliteration to some extent after the operative treatment of VSNs. The coronal reformatted images serve to improve the conspicuity of obliteration. Factors, such as size, intrameatal or intracanalicular extension of the tumors, and age could not be demonstrated to affect the rate of cochlear

obliteration significantly. The cochlear obliteration was more common in females. The prohibition of cochlear ossification via retrosigmoid approach, compared to the other CPA approaches, would be a subject of future studies.

Conflict of Interest

None.

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