

Prognostic Significance of Changes in the Internal Acoustic Meatus Caused by Vestibular Schwannoma

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Abstract

The prognostic significance of the variety of changes in the internal auditory meatus (IAM) caused by vestibular schwannoma was retrospectively analyzed in 69 consecutive patients with vestibular schwannoma. Preoperative bone-window computed tomography was used to classify IAM changes into extensive destruction (17%), widening (46%), and normal IAM (36%). Extensive destruction (47 ± 19 years) and widening (48 ± 13) occurred in significantly younger patients than normal IAM (59 ± 9). Preoperative hearing was significantly more severely disturbed in patients with extensive destruction than in those with widening or normal IAM. IAM change was significantly related to the tumor consistency, as normal IAM was more common in patients with cystic tumor than in those with solid tumor. Postoperative hearing and facial function were worse in patients with severe IAM change, although the relationship between the IAM change and the surgical result was not significant. One patient with extensive destruction developed postoperative cerebrospinal fluid (CSF) leakage through the air cells around the IAM, and needed surgical repair. Severe IAM change occurs with solid tumor and causes severely disturbed preoperative hearing in younger patients, which reflects the tumor aggressiveness. Severe IAM change increases the technical difficulty of tumor removal and the risk of postoperative CSF leakage, and is associated with a poorer prognosis for patients with vestibular schwannoma.

Key words: cerebrospinal fluid leakage, internal auditory meatus, prognosis, tumor removal, vestibular schwannoma

Introduction

Vestibular schwannoma originates in the Schwann cell-glial junction lateral to the porus acusticus²⁴⁾ and continues to grow in the internal auditory meatus (IAM). Long-standing growth of the intrameatal tumor may cause changes in the IAM, appearing to various extents and outlines. Normal IAM is found in 10% of surgically verified tumors,²⁵⁾ whereas extensive destruction of the IAM is often found with medium size tumors.²⁾ The change in the IAM may reflect the tumor characteristics, affect surgical planning, and determine the prognosis. The prognostic significance of change in the IAM was retrospectively investigated in 69 consecutive patients with vestibular schwannoma.

Materials and Methods

This study included 69 patients with vestibular schwannoma, 33 males and 36 females aged 8-72 years (mean \pm SD 52 ± 14 years), who underwent tumor removal via the retrosigmoid suboccipital transmeatal approach. Patients with neurofibromatosis type 2 were excluded.

Preoperative bone-window computed tomography (CT) (1.0 mm or 1.5 mm slice thickness) was used to classify the change in the IAM due to vestibular schwannoma into extensive destruction, widening, and normal (Fig. 1). Extensive destruction was defined as extensive destruction of the petrous bone around the IAM and complete loss of the original outline. Widening was defined as asymmetrical widening of the IAM ipsilateral to the vestibular schwannoma compared with the contralateral IAM, but with preservation of the original outline. Normal was defined as symmetrical IAMs on both sides with a difference in the diameter of the bilateral IAMs of

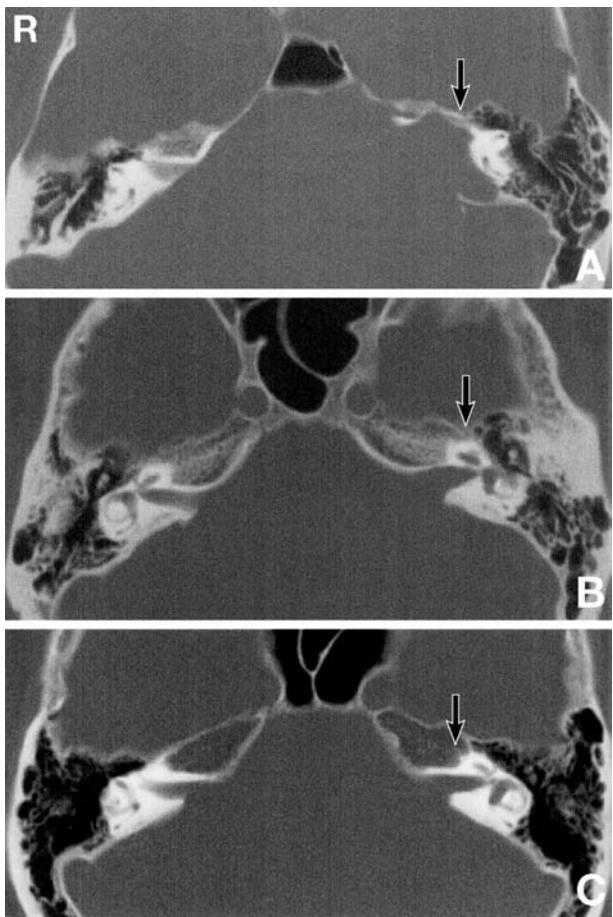


Fig. 1 Computed tomography classification of changes in the internal auditory meatus due to vestibular schwannoma: (A) extensive destruction, (B) widening, and (C) normal. arrow: Side of the tumor.

less than 2 mm.^{8,28)}

The medical records, magnetic resonance (MR) imaging, and CT of the 69 patients were retrospectively studied to analyze the clinical presentation, neuroimaging characteristics, pneumatization near the IAM, and the result of tumor removal. The relationships between the IAM change and these parameters were evaluated. The data were statistically analyzed using the chi-square test for independence and one-factor analysis of variance followed by Fisher's protected least significant difference.

Results

I. Clinical presentations (Table 1)

Twelve of the 69 tumors (17%) showed extensive destruction, 32 (46%) showed widening, and 25 (36%) were normal. Patients with extensive destruction and widening were significantly younger than

patients with normal IAM. Extensive destruction showed female predominance (male:female = 1:2), but not significantly. The preoperative hearing level of the pure-tone average (PTA) in 69 patients was 59 ± 29 dB. Patients with extensive destruction had significantly more disturbed hearing than patients with widening or normal IAM.

Thirty-six of 63 patients (57%) presented with trigeminal nerve dysfunction. The incidence of the trigeminal nerve dysfunction was 7/12 (58%) with extensive destruction, 17/32 (53%) with widening, and 12/25 (48%) with normal, showing no significant difference. None of the 69 patients had preoperative facial nerve paresis.

II. Neuroimaging characteristics and pneumatization (Table 2)

Preoperative MR imaging was used to determine the size and the consistency of tumor. The mean tumor size measured by the maximal diameter of the extrameatal tumor was 29 ± 14 mm. The tumor size was not significantly different between three patient groups. The tumor consistency was classified into either cystic (19%) or solid. A cystic tumor consisted mainly of either a large cyst or multiple cysts. A solid tumor showed either no cyst formation or only minimal cyst formation. Cystic tumors were significantly more common in patients with normal IAM (40%) than in those with extensive destruction (8%) or widening (6%) (Figs. 2 and 3).

Preoperative bone-window CT of the skull base was used to determine pneumatization near the IAM, i.e., pneumatization in the posterior wall of the IAM and in the petrous apex (Fig. 4). The IAM posterior wall was pneumatized in 13 of 69 patients (19%). The incidence of pneumatized posterior wall was not significantly different between three patient groups. The petrous apex was pneumatized in 20 of 69 patients (29%). The incidence of the pneumatized petrous apex was not significantly different between the three groups.

III. Results of tumor removal (Table 3)

The tumor was removed either totally or near-totally¹²⁾ in 64 of 69 patients (93%). The tumor removal was subtotal (<95% removal of tumor)¹²⁾ in five patients, one with extensive destruction, two with widening, and two with normal IAM. The incidence of subtotal removal was not significantly different between the three groups.

Hearing was preserved postoperatively in eight of 69 patients (12%), Class A or Class B according to the guidelines of the Committee on Hearing and Equilibrium of the American Academy of Otolaryngology-Head and Neck Surgery Foundation (1995).⁵⁾

Table 1 Clinical presentations and changes in the internal auditory meatus (IAM)

IAM change	No. of patients			Age* (years)	PTA* (dB)
	Total	Male [#]	Female [#]		
Extensive destruction	12	4	8	47 ± 19 [†]	78 ± 22
Widening	32	16	16	48 ± 13 ^{††}	52 ± 29 [‡]
Normal	25	13	12	59 ± 9	58 ± 30 ^{‡‡}
Total	69	33	36	52 ± 14	59 ± 29

*Values are means ± SD. [#]p = 0.54 by chi-square test for independence. [†]p = 0.007, ^{††}p = 0.002 versus age of patients with normal IAM by Fisher's protected least significant difference (PLSD) after one-factor analysis of variance (ANOVA). [‡]p = 0.008, ^{‡‡}p = 0.048 versus pure-tone average (PTA) in patients with extensive destruction of IAM by Fisher's PLSD after one-factor ANOVA.

Table 2 Neuroimaging characteristics and pneumatization near the internal auditory meatus (IAM)

IAM change	Tumor size* (mm)	Tumor consistency [#]		Pneumatization in the posterior wall [†]		Pneumatization in the petrous apex [‡]	
		Cystic	Solid	Present	Absent	Present	Absent
Extensive destruction	32 ± 10	1	11	2	10	4	8
Widening	28 ± 13	2	30	6	26	10	22
Normal	28 ± 17	10	15	5	20	6	19
Total	29 ± 14	13	58	13	56	20	49

*Values are means ± SD of maximal diameter of the extrameatal tumor measured by magnetic resonance imaging. p = 0.68 by one-factor analysis of variance. [#]p = 0.003, [†]p = 0.97, [‡]p = 0.78 by chi-square test for independence.

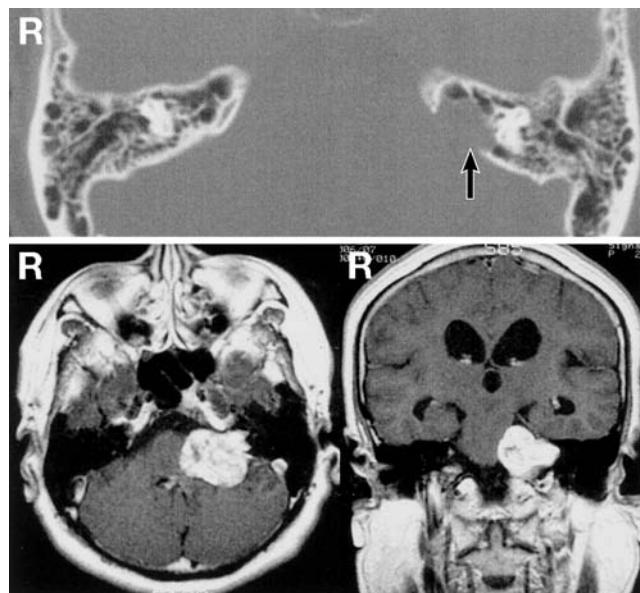


Fig. 2 Computed tomography scan (upper) and magnetic resonance images (lower) showing a solid vestibular schwannoma with extensive destruction (arrow).

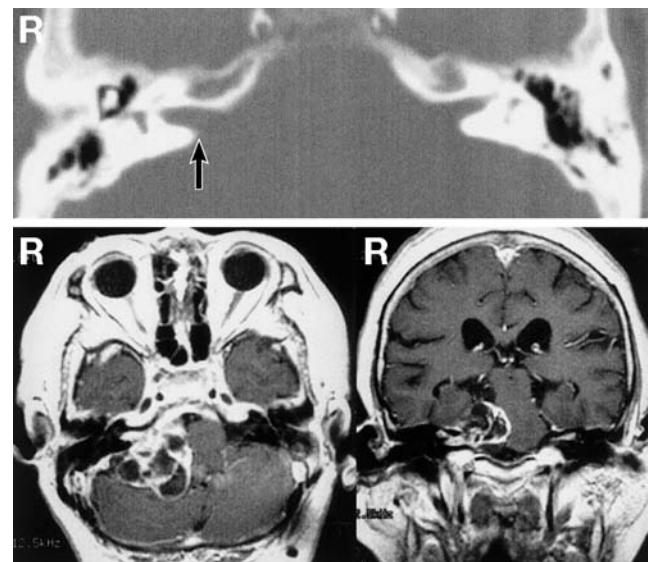


Fig. 3 Computed tomography scan (upper) and magnetic resonance images (lower) showing a cystic vestibular schwannoma with normal internal auditory meatus (arrow).

i.e., the PTA was ≤ 50 dB and the speech discrimination score was $\geq 50\%$. Hearing was preserved in none of 12 patients with extensive destruction. However, the incidence of the hearing preservation was not significantly different between the three groups.

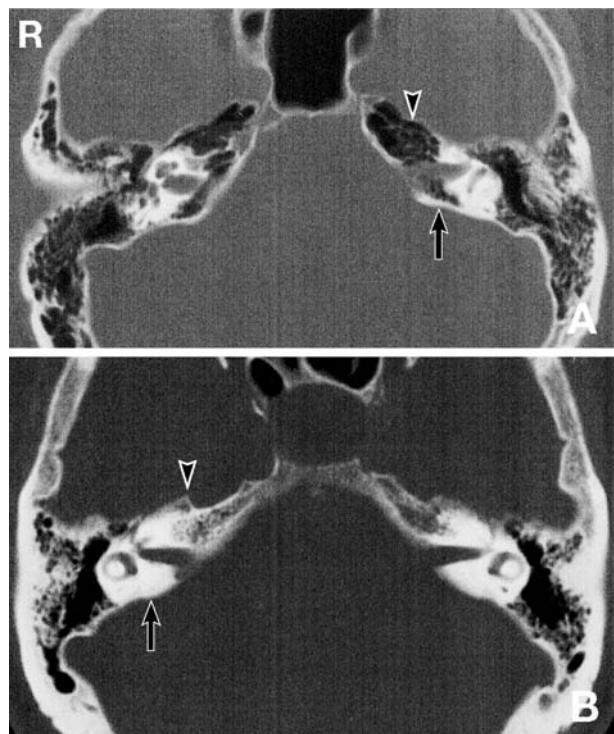


Fig. 4 Bone-window computed tomography scans showing pneumatization near the internal auditory meatus (IAM), the petrous apex (arrowhead), and the posterior wall of the IAM (arrow). The petrous apex and the posterior wall are pneumatized in the tumor on the left (A), but not in the tumor on the right (B).

The facial nerve was anatomically preserved during tumor removal in 64 of 69 patients (93%). The rate of facial nerve anatomical preservation was not different between the three groups. The facial function 1 year after tumor removal was good (House-Brackmann grades 1–2)¹⁰⁾ in 59 of 69 patients (86%). The rates of the postoperative good facial function in patients with extensive destruction (75%) and widening (84%) were lower than in patients with normal IAM (92%), but the difference was not significant.

Cerebrospinal fluid (CSF) leakage occurred in three patients. Two patients developed CSF leakage through the mastoid air cells exposed by the suboccipital craniotomy, and were treated only by lumbar CSF drainage. One patient with extensive destruction developed CSF leakage through the air cells

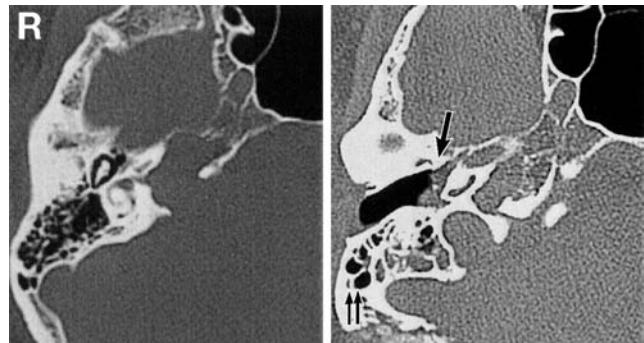


Fig. 5 (left) Preoperative computed tomography (CT) scan showing extensive destruction caused by a vestibular schwannoma. (right) Postoperative CT scan showing cerebrospinal fluid leakage through the air cells around the internal auditory meatus, with the middle ear cavity filled with fluid (arrow) and the mastoid air cells not filled with fluid (double arrow).

Table 3 Results of tumor removal and changes in the internal auditory meatus (IAM)

IAM change	Hearing [#]		Facial nerve [†]		Facial function ^{**,‡}	
	Preserved*	Not preserved	Preserved	Not preserved	Good	Poor
Extensive destruction	0	12	11	1	9	3
Widening	5	27	29	3	27	5
Normal	3	22	24	1	23	2
Total	8	61	64	5	59	10

*Class A or B according to the guidelines of the Committee on Hearing and Equilibrium of the American Academy of Otolaryngology-Head and Neck Surgery Foundation.⁵⁾ **good: House-Brackmann grades 1–2, poor: House-Brackmann grades 3–6.¹⁰⁾ [#]p = 0.38, [†]p = 0.73 by chi-square test for independence.

around the IAM (Fig. 5). Lumbar CSF drainage did not cure the leakage, so surgical repair was performed.

Discussion

Changes in the IAM caused by vestibular schwannoma show great variation in extent and outline. Several complicated diagnostic classifications have been proposed including types such as erosion, flaring, asymmetrical widening, and shortening of the posterior wall of the IAM.^{8,27)} However, MR imaging has diminished the diagnostic significance of the IAM change and the necessity for complicated classification. To evaluate the prognostic significance, we simply classified IAM changes in our 69 patients with vestibular schwannoma into three types, extensive destruction, widening, and normal.

Both extensive destruction and widening occurred in significantly younger patients than normal IAM. Vestibular schwannoma in younger patients presents with more aggressive characteristics including faster growth¹⁸⁾ and hypervascularity.^{15,30)} The tumor aggressiveness is related to the severe IAM changes seen in younger patients.¹⁷⁾

The preoperative hearing loss was significantly more severe in the patients with extensive destruction than in those with widening or normal IAM. Hearing loss due to vestibular schwannoma is caused by either ischemia of the cochlea^{20,23)} or a conduction block of the cochlear nerve.^{4,14)} The cochlea is supplied by the branches of the labyrinthine artery that often have no anastomosis, so a compromise of the artery in the IAM results in ischemia of the cochlea. Minimal compression of the cochlear nerve also causes conduction block of the nerve.⁴⁾ A large intrameatal tumor, associated with extensive destruction, increases the pressure in the meatus, which compromises the labyrinthine artery and causes compression of the cochlear nerve.

The IAM change was not related to the size of extrameatal tumor, but was significantly related to the tumor consistency. A solid tumor causes severe IAM change more often than a cystic tumor. A cystic tumor grows rapidly by the expansion of the cystic components,^{3,6,11)} which explains the rareness of severe IAM change. A cisternal vestibular schwannoma growing exclusively in the cerebellopontine cistern has no intrameatal tumor extension, and so causes no IAM change.³¹⁾

The pneumatization in the petrous bone is extremely complicated and also shows enormous variation in extent and arrangement.^{1,21)} Bone-window CT can visualize complex petrous pneumatization.²⁹⁾ Bone-window CT evaluation of petrous pneumatiza-

tion around the IAM found no significant relationship between the IAM change and the petrous pneumatization. The increased pressure in the meatus due to vestibular schwannoma initiates the IAM change, but causes hyperemia rather than ischemia due to an inflammatory reaction in the petrous bone around the IAM, and results in bone resorption.^{2,26)} Even sclerotic petrous bone without pneumatization is not resistant to bone resorption. We found no significant relationship between IAM change and sex. Osteoporosis, characterized by reduced bony strength, is prevalent among postmenopausal women.¹⁶⁾ However, osteoporosis of the petrous bone is not related to the IAM change. Therefore, the severity of IAM change is determined by the characteristics of the tumor rather than those of the petrous bone around the IAM.

The results of tumor removal demonstrated that postoperative hearing and facial function were worse in patients with severe IAM change, which may be explained by the technical difficulty in the removal of a large intrameatal tumor associated with such change. CSF leakage occurs in 10% of cases after suboccipital transmeatal removal of vestibular schwannoma.⁹⁾ There are two potential routes for CSF leakage, the mastoid air cells exposed by the suboccipital craniotomy and the surrounding air cells exposed by IAM opening.^{7,13,19,22)} CSF leakage through the air cells around the IAM occurs less frequently, but is less likely to be cured by lumbar CSF drainage and may need surgical treatment.²²⁾ Our patient with extensive destruction who developed CSF leakage through the air cells around the IAM needed surgical treatment. The air cells around the IAM are exposed preoperatively by severe IAM change. The removal of a large intrameatal tumor associated with severe IAM change needs extensive resection of the petrous bone, which increases the risk of CSF leakage.¹⁹⁾ Therefore, severe IAM change increases the risk of CSF leakage.

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Commentary

The authors have introduced a new scale of changes of the inner auditory meatus (IAM) in connection with vestibular schwannoma. Their grading into extensive destruction and/or widening of the IAM, and normal IAM point to important properties concerning the character of the tumor inside the canal. The general points about this relationship were known already. However, what matters are the prognostic factors, the changes in the IAM, which are very important in the prediction of the outcome of surgical treatment. If one may conclude that in younger patients with an extensive destruction of the IAM, complications following (complete) removal of the tumor are very probable, the surgeon should question himself as to what would be the best option for the patient: total or gross-total removal. Until recently, all of us who were inclined to complete surgical removal of a schwannoma from the CPA and from the IAM should reconsider our belief. The reasons for that are at least two: the first is not to create unnecessary deficits, and the second, not less important — the rest of the lesion could be hit by radiosurgery. It is extremely important to obtain precise and objective preoperative data regarding the function of nerves VII and VIII. In combination with

the preoperative deficits and findings with imaging, one has more to offer to the patient — prior to surgery — to help him/her to be objective and active in decision-making regarding the extent of surgical resection of the lesion, and possible combination with radiosurgical treatment after surgery.

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In this article, Yamakami and co-workers have retrospectively analyzed the effect of destruction of the internal auditory meatus (IAM) on preoperative neurological status, intraoperative findings, and postoperative results in patients suffered from of intra-extrameatal vestibular schwannomas. Preoperative bone-window computed tomography was used to classify the changes in the IAM due to vestibular schwannoma into extensive destruction, widening, and normal. According to the well-known surgical experience, the authors have found significantly more hearing disturbances in patients with extensive destruction than in those with widening or normal IAM. The tumors causing extensive destruction were solid lesions, cystic lesions were significantly common in patients with normal IAM. Severe IAM changes occurred in significantly younger patients, which may reflect the tumor aggressiveness. Concerning intraoperative findings and surgical results, the authors could not preserve hearing function in patients with extensive destruction, however, the incidence of hearing preservation was not significantly different between the three groups. The rates of postoperative good facial function in patients with extensive destruction and widening were lower than in patients with normal IAM. These results correspond to our surgical experiences and to the well-known international literature. Despite the fact, that this article does not describe new informations, the accurate statistical analysis and interesting discussion may offer wide acceptance of the paper.

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In this paper, the pattern of IAM destruction was classified into three types with correlating clinical features, tumor characteristics, and surgical outcome. Interestingly, severe IAC changes were related to younger age, preoperative hearing impairment, tumor aggressiveness or consistency, and the poor outcome. However, as far as the available methodology is MRI and CT, 69 cases might not be enough to draw a definite conclusion. Accordingly, I would like to comment on the possible advantage of the present paper for planning operative strategy.

In cases with extensive destruction of IAC, sur-

geons need minimum bone drilling with particular attention paid only to the preservation of the facial nerve, because the patients frequently present with hearing loss. The most probable pitfall is the postoperative CSF leakage, because of drilling out of the paper-thin cortical bone covering the mastoid air cells. For prevention, surgeons must plan the extent of bone drilling carefully, and at the opening of the air cells during surgery, patching the hole with muscle embedded in fibrin-glue is recommended rather than bone wax. Furthermore, a diamond burr rather than a steel burr is recommended because of the fragile or absent IAC dura mater.

In cases with extensive destruction, the temporal fossa approach is preferable to the retrosigmoid approach, if the extrameatal tumor is tiny. In this situation, the meatal plane anterior to the arcuate eminence is drilled down only a few millimeters to access the upper aspect of the IAC. If the IAC tumor is large and compresses very thin nerves, drilling of the lateral portion close to the fundus is helpful to find and dissect the demarcation between the tumor and the normal VII-VIII complex. In this situation, great attention should be paid not to injure the labyrinthine segment (the most vulnerable) of the facial nerve. Total removal of the tumor can be achieved only by extradural procedures. The petrous bone defect is patched by reflecting the temporal fascia to avoid CSF leakage.

Regardless of the extent of IAC destruction, the trans-labyrinthine approach is indicated if the patients show marked hearing loss and the cerebellopontine angle tumor is relatively small (less than 2 cm). During this procedure, surgeons should always consider the precise localization and shape of the IAC within the petrous bone. If the reflection of dura mater covering the medial aspect of petrous bone is observed, the IAC is located just vertical from there in the direction of the geniculate ganglion. Drilling is continued until the paper-thin covering cortex appears, which can be taken away by microdissector without injuring the dura mater of the IAC. After resecting the tumor within the IAC, the cerebellopontine angle tumor may be appreciated by gently compressing the VII-VIII complex.

In summary, skillful surgeons should master the three choices for approaching vestibular schwannomas: the retrosigmoid, temporal fossa, and trans-labyrinthine approaches. The extent of preoperative hearing impairment, bone destruction, and the size of the cerebellopontine angle tumor may be the key factors determining the most suitable approach. In this sense, the present paper is quite helpful for both neurosurgeons and ENT surgeons not only to predict the clinical outcome but also to plan the operative strategy.

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