Evaluation of Variation in the Course of the Facial Nerve, Nerve Adhesion to Tumors, and Postoperative Facial Palsy in Acoustic Neuroma

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Abstract

Objective To investigate the variation in the course of the facial nerve (FN) in patients undergoing acoustic neuroma (AN) surgery, its adhesion to tumors, and the relationship between such adhesions and postoperative facial palsy.

Methods The subjects were 356 patients who underwent AN surgery in whom the course of the FN could be confirmed. Patients were classified into six groups: ventro-central surface of the tumor (VCe), ventro-rostral (VR), ventro-caudal (VCa), rostral (R), caudal (C), and dorsal (D).

Results The FN course was VCe in 185 cases, VR in 137, VCa in 19, R in 10, C in 4, and D in one. For tumors < 1.5 cm, VCe was most common. For tumors ≥ 1.5 cm, the proportion of VR increased. No significant difference was observed between the course patterns of the FN in terms of postoperative FN function, but for tumors > 3.0 cm, there was an increasing tendency for the FN to adhere strongly to the tumor capsule, and postoperative facial palsy was more severe in patients with stronger adhesions.

Conclusions The VCe pattern was most common for small tumors. Strong or less strong adhesion to the tumor capsule was most strongly associated with postoperative FN palsy.

Keywords
- acoustic neuromas
- facial nerve
- retrosigmoid approach
- adhesion

Introduction

The goals of acoustic neuroma surgery are safe tumor resection, hearing preservation, and preservation of facial nerve function. In recent years, operative results reported by expert skull base teams working with innovative microsurgical instruments have improved markedly, with the incidence of facial nerve palsy being only a few percent. In general, during acoustic neuroma surgery, surgeons proceed with removal while confirming the position of the facial nerve, the course of which is known to vary according to factors such as tumor size, site of origin, and degree of adhesion. Since accurate preoperative assessment of the anatomical location and course of the facial nerve is difficult even with current

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advances in imaging technology, the only method currently available is confirmation under a microscope with repeated intraoperative facial nerve stimulation. In this study, the associations of facial nerve course patterns in acoustic neuroma with adhesion to tumors and postoperative facial palsy were investigated.

Material and Methods

The subjects were 356 patients undergoing surgery for acoustic neuroma via the retrosigmoid approach between April 2002 and December 2010 (160 women and 196 men; mean age, 59.1 years; mean tumor size, 19.8 mm).

In all cases, total or near-total removal of the tumor was attempted, and the facial nerves were anatomically preserved. All procedures were performed by expert neurosurgical teams with intraoperative facial nerve monitoring and intraoperative auditory brain stem response monitoring for hearing preservation.

The data obtained included patient age, tumor size (evaluated as the largest transverse diameter on enhanced magnetic resonance (MR) images, with the intracanalicular component excluded), pre- and postoperative facial nerve function, and extent of adhesions between the facial nerve and the tumor.

The course of the facial nerve was classified into six patterns according to its path on the surface of the tumor: ventro-central (VCe), ventro-rostral (VR), ventro-caudal (VCa), rostral (R), caudal (C), and dorsal (D). In the case of particularly large tumors, the patterns in all cases could not be fit, and so the course in the vicinity of the internal auditory canal—where adhesions were the strongest and separation was most difficult—was evaluated. During this period, there were 32 cases that ended with partial removal, depending on the age of the patient and degree of adhesion. In these cases, the course of the facial nerve could not be seen completely. Such patients are not included in the present data.

All 356 patients exhibited normal (grade 1) facial function preoperatively. In addition, the facial nerve was anatomically preserved after surgery in all cases. Facial nerve outcome was reported on the House-Brackmann scale,[1] and the results are recorded as early (approximately 2 weeks after surgery) or late (8 to 12 months after surgery).

Strong or less strong adhesion between the tumor and the facial nerve was evaluated during the procedure by the first author. The surgeon's subjective perceptions had a major influence when evaluating the degree of adhesion of the facial nerve to the tumor, as there is no scale for the degree of adhesion. Less strong adhesions were therefore defined as adhesions in which the facial nerve could be separated from the tumor comparatively easily with a microdissector, and strong adhesions were defined as those that were difficult to separate, requiring sharp dissection with microscissors.

Results

The Course of the Facial Nerve

The VCe pattern (i.e., that in which the facial nerve ran ventrally and centrally over the tumor surface) accounted for 185/356 cases (52.0%), the largest proportion of cases overall, followed by VR in 137 cases (38.5%), VCa in 19 (5.3%), R in 10 (2.8%), C in 4 (1.1%), and D in 1 (0.3%) (►**Table 1**). Categorized by tumor size, for tumors $<$ 1.5 cm, the pattern was VCe in 77/98 cases (78.6%) and VR in 21 (21.4%); for tumors of 1.5 to 3.0 cm, the pattern was VCe in 90/195 cases (46.2%), VR in 89 (45.6%), VCa in 11 (5.6%), R in 3 (1.5%), C in 1 (0.5%), and D in 1 (0.5%); and for tumors $>$ 3.0 cm, the pattern was VCe in 18/63 cases (28.6%), VR in 27 (42.9%), VCa in 8 (12.7%), R in 7 (11.1%), and C in 3 (4.8%). That is, for tumors $<$ 1.5 cm, the VCe pattern was the most common, accounting for nearly 80% of cases. For tumors $\geq$ 1.5 cm, the proportion of VR rose, and once tumor size exceeded 3.0 cm, there was an increase in the proportion of patients with severely distorted courses, such as the R pattern, in which the nerve runs across the upper peak of the tumor, or the VCa and C patterns, in which it runs along the caudal side. In one patient (tumor size 2.4 cm), the course ran entirely along the dorsal side.

Facial Nerve Outcome (Late) According to the House-Brackmann Scale

►**Table 2** shows facial nerve function according to the House-Brackmann scale[1] for each facial nerve course pattern at late follow-up examination (8 to 12 months). Grade 1 patients accounted for 131 cases (70.8%) of VCe, 99 (72.3%) of VR, 15 (78.9%) of VCa, 8 (80.0%) of R, and 2 (50.0%) of C; Grade 2 patients accounted for 40 cases (21.6%) of VCe, 31 (22.6%) of VR, 1 (5.3%) of VCa, and 1 (10.0%) of R; Grade 3 patients accounted for 9 cases (4.9%) of VCe, 5 (3.6%) of VR, 2 (10.5%) of VCa, 1 (10.0%) of R, 2 (50.0%) of C, and 1 (100%) of D; and Grade

Table 1 Facial nerve course patterns by tumor size

	Course of facial nerve						
Tumor size (cm)	No. of patients	VCe	VR	VCa	R	C	D
$<$ 1.5	98	77 (78.6%)	21 (21.4%)	0	0	0	0
1.5–3.0	195	90 (46.2%)	89 (45.6%)	11(5.6%)	3 (1.5%)	1 (0.5%)	1 (0.5%)
$>$ 3.0	63	18 (28.6%)	27 (42.9%)	8 (12.7%)	7 (11.1%)	3 (4.8%)	0
Total	356	185 (52.0%)	137 (38.5%)	19 (5.3%)	10 (2.8%)	4 (1.1%)	1 (0.3%)

Abbreviations: C, caudal pattern; D, dorsal pattern; R, rostral pattern; VCa, ventro-caudal pattern; VCe, ventro-central pattern; VR, ventro-rostral pattern.

Table 2 Postoperative facial nerve outcome (late) according to the House-Brackmann scale for each facial nerve course pattern

	Course of facial nerve					
Grade	VCe	VR	VCa	R	C	D
1	131 (70.8%)	99 (72.3%)	15 (78.9%)	8 (80.0%)	2 (50.0%)	0
2	40 (21.6%)	31 (22.6%)	1 (5.3%)	1 (10.0%)	0	0
3	9 (4.9%)	5 (3.6%)	2 (10.5%)	1 (10.0%)	2 (50.0%)	1 (100%)
4	5 (2.7%)	2 (1.5%)	1 (5.3%)	0	0	0
5	0	0	0	0	0	0
6	0	0	0	0	0	0
Total	185	137	19	10	4	1

Abbreviations: C, caudal pattern; D, dorsal pattern; R, rostral pattern; VCa, ventro-caudal pattern; VCe, ventro-central pattern; VR, ventro-rostral pattern.

4 patients accounted for 5 cases (2.7%) of VCe, 2 (1.5%) of VR, and 1 (5.3%) of VCa. Excluding patterns C and D, which were seen in only small numbers of patients, there were no major differences in outcome for different facial nerve course patterns in terms of postoperative facial nerve function.

Adhesion between the Tumor and the Facial Nerve

►**Table 3** shows strong or less strong adhesion between the tumor capsule and the facial nerve in terms of course pattern and tumor size. Adhesion was present in 22 cases (28.6%) of VCe and 8 (38.1%) of VR for tumors < 1.5 cm; 49 cases (54.4%) of VCe, 49 (55.1%) of VR, 3 (27.3%) of VCa, 2 (66.7%) of R, 1 (100%) of C, and 1 (100%) of D for tumors 1.5 to 3.0 cm; and 14 cases (77.8%) of VCe, 22 (81.5%) of VR, 5 (62.5%) of VCa, 6 (85.7%) of R, and 2 (66.7%) of C for tumors > 3.0 cm. There were no major differences among VCe, VR, and VCa in terms of extent of adhesion, but strong adhesion was frequent in cases of R, C, and D, courses that ran in an extremely distorted pattern. Strong adhesion was more frequent for larger tumors in all course patterns.

The site of strongest adhesion was in the region of the entrance to the internal auditory canal in all course patterns.

Postoperative Facial Nerve Function (Late) and Tumor Adhesion to the Facial Nerve

A comparison of postoperative facial nerve function in relation to strong or less strong tumor adhesion showed that strong adhesion had a significant effect on facial nerve preservation outcomes (►**Table 4**). In some cases, the facial nerve was embedded within the tumor capsule, resulting in a higher rate of postoperative facial palsy.

Changes in Facial Nerve Morphology

When the tumor was larger than 3.0 cm, the facial nerve tended to become thinned and flattened and to adhere to the tumor capsule more strongly.

Discussion

The goals of acoustic neuroma surgery are safe, accurate, and complete tumor resection, hearing preservation, and facial nerve preservation.[2–8] To accomplish microsurgical total tumor resection with curative intent in patients without any complications, surgeons must have a detailed understanding of temporal bone and cerebellopontine angle anatomy and use precise and sophisticated micro-technical skills, as well as abundant clinical experience.[9–11] In recent years, operative results reported by expert skull base teams working with innovative microsurgical instruments have improved markedly, with the incidence of facial nerve palsy being only a few percent.[12,13] Normally, hearing impairment is the primary complaint in acoustic neuroma, with preoperative facial nerve palsy hardly ever present, meaning that preservation of this function requires the most care.

In general, during acoustic neuroma surgery, resection proceeds while confirming the position of the facial nerve,

Table 3 Presence of strong adhesions in relation to tumor size and facial nerve course patterns

	Course of facial nerve					
Tumor size (cm)	VCe	VR	VCa	R	C	D
< 1.5	22/77 (28.6%)	8/21 (38.1%)	0	0	0	0
1.5–3.0	49/90 (54.4%)	49/89 (55.1%)	3/11 (27.3%)	2/3 (66.7%)	1/1 (100%)	1/1 (100%)
> 3.0	14/18 (77.8%)	22/27 (81.5%)	5/8 (62.5%)	6/7 (85.7%)	2/3 (66.7%)	0
Total	85/185 (45.9%)	79/137 (57.7%)	8/19 (42.1%)	8/10 (80.0%)	3/4 (75.0%)	1/1 (100%)

Abbreviations: C, caudal pattern; D, dorsal pattern; R, rostral pattern; VCa, ventro-caudal pattern; VCe, ventro-central pattern; VR, ventro-rostral pattern.

Table 4 Strong or less strong adhesions and postoperative facial nerve palsy

	Postoperative grade[a]				
	1	2	3	4	5
Strong adhesion	113 (44.3%)	47 (64.4%)	16 (80.0%)	8 (100.0%)	0
Less strong adhesion	142 (55.7%)	26 (35.6%)	4 (20.0%)	0	0
Total	255	73	20	8	0

[a]According to the House-Brackmann grading system.

the course of which is known to vary according to factors such as tumor size, site of origin, and degree of adhesion. Accurate preoperative assessment of the anatomical location and course of the facial nerve is difficult even with the current rapid development of imaging technologies such as MR imaging. Particularly with large tumors, the facial nerve can be compressed and flattened into a thin structure that adheres strongly to the tumor capsule, and sometimes it even becomes infiltrated or enfolded into the tumor. Because this makes it difficult to confirm the course accurately, even under a microscope, the only method currently available is cautious confirmation of its course with repeated intraoperative facial nerve stimulation while removing the tumor. We performed frequent intraoperative facial nerve stimulation,[14] identifying the root exit zone of the facial nerve at the earliest possible stage and placing the electrode for continuous stimulation monitoring at that point during tumor removal surgery.

In small acoustic neuromas, the course of the facial nerve can often be confirmed preoperatively by MR cisternography, and Taoka et al have reported the use of diffusion tensor tractography for preoperative evaluation of the displacement of the facial nerve course in vestibular schwannoma. This could be represented in seven of eight cases, and in five of these seven cases the representation was consistent with intraoperative findings. In the cases in which it was not consistent, the tumor was extremely large (47 mm) or mostly cystic.[15] Gerganov et al used diffusion tensor imaging–based fiber tracking and reported that the results were consistent with intraoperative findings in 91% of cases of large vestibular schwannoma.[16] Future advances in these MR imaging techniques may enable even more accurate preoperative evaluation.

With respect to facial nerve course patterns, in the present series, courses crossing the ventro-central surface accounted for around 80% of cases of small acoustic neuromas of $<$ 1.5 cm. In contrast, for tumors measuring between 1.5 and 3 cm, the frequency of VCe was very similar to that of VR (46.2% versus VR in 45.6%), and for tumors $>$ 3.0 cm, the course had shifted to the ventro-rostral surface in many cases, with VCe accounting for 28.6% of cases and VR for 42.9%. In the present series, a course across the dorsal portion of the tumor was seen in only one patient (0.3%).

Sampath et al[17] analyzed microanatomical variations in the location of the facial nerves for 1006 cases of acoustic neuromas categorized by size, but with measurements 1.0 cm larger than our classification (Group I: smaller than 2.5 cm; Group II: between 2.5 cm and 4.0 cm; and Group III: larger than 4.0 cm). In their patients, the facial nerve most commonly ran across the anterior middle third of the tumor (corresponding to VCe in our classification); this pattern was seen in 40.0% of cases in Group I, 40.2% in Group II, and 39.8% in Group III, followed by the anterior superior third (corresponding to VR) in 33.5% of cases in Group I, 33.2% in Group II, and 32.7% in Group III, and the posterior location (corresponding to D) in 1.6% of cases in Group I, 2.5% in Group II, and 2.6% in Group III. There were no differences in course frequency among different sizes of tumor.

In a study of 163 cases of acoustic neuroma, Bae et al[18] categorized facial nerve course patterns into four groups: (1) the ventral and superior surface of the tumor (corresponding to VR in our classification); (2) the ventral and central surface (corresponding to VCe); (3) the ventral and inferior surface (corresponding to VCa); and (4) the dorsal surface (corresponding to D). They found that the course ran across the ventral and superior surface in 55.8% of cases, the ventral and central surface in 35.0%, the ventral and inferior surface in 8.6%, and the dorsal surface in 0.6%. For tumors $<$ 2.0 cm in diameter, the ventral and central surface pattern was most common, occurring in 65.2% of cases, whereas for tumors of diameter $>$ 2.0 cm, the ventral and superior surface was the most common, occurring in 59.3%. As in the present series, the course increasingly shifted to the rostral side with increasing tumor size. With the retrosigmoid approach, Rand et al[19,20] reported that the dorsal pattern with the nerve running on the operator's side of the tumor was present in 7 to 9% of cases. However, for this type of pattern, Sampath et al[17] reported a frequency of 1.6 to 2.6%, and Bae et al[18] noted one of 0.6%; this pattern was also extremely rare in the present series, seen in only one case (0.3%).

If the small number of cases with patterns C and D is excluded, there was no difference with respect to postoperative facial nerve function among VCe, VR, VCa, and R, and around 90% of patients were Grade 2 on the House-Brackmann scale after 8 to 12 months. When the facial nerve is located on the dorsal aspect of the tumor, however, tumor resection is performed across the facial nerve from the start, meaning that postoperative palsy (Grade 3) occurs more easily due to excessive manipulation of the nerve.

With respect to strong or less strong adhesion of the facial nerve to the tumor, there were no major differences among VCe, VR, and VCa in terms of course pattern, but strong adhesion was frequent in cases of R, C, and D, courses that ran in an extremely distorted pattern. Strong adhesion was more frequent for larger tumors in all course patterns, with stronger pressure from the tumor on the nerve resulting in it becoming morphologically stretched and flattened, with a higher chance of adhering strongly to the tumor capsule and even becoming incorporated within the tumor in some cases. Sampath et al[17] reported that "the facial nerve passed through the tumor itself (infiltrating tumor or enfolded by tumor)" in around 3% of cases, but unlike the present series, this was not related to tumor size. The site of strongest adhesion was in the region of the internal acoustic foramen in all course patterns, and since there was a tendency for longer latency and smaller amplitude during continuous stimulation monitoring for resections in this area, this location is regarded as having the highest risk of causing facial nerve damage. Accordingly, in recent cases, we have been performing subtotal removal if there is severe adhesion between the facial nerve and the tumor, leaving part of the tumor capsule along the course of the facial nerve, with the goal of facial nerve preservation.

Conclusions

When performing acoustic neuroma surgery, attempts should be made to preserve hearing acuity and to accurately identify the course of the facial nerve to preserve its function. Since it remains difficult to accurately identify the course of the facial nerve on preoperative images, surgical manipulation must be performed carefully and precisely, using appropriate measures such as frequent intraoperative nerve stimulation and continuous stimulation monitoring.

References

1 House JW, Brackmann DE. Facial nerve grading system. Otolaryngol Head Neck Surg 1985;93:146–147
2 Fischer G, Fischer C, Rémond J. Hearing preservation in acoustic neurinoma surgery. J Neurosurg 1992;76:910–917
3 Glasscock ME III, Hays JW, Minor LB, Haynes DS, Carrasco VN. Preservation of hearing in surgery for acoustic neuromas. J Neurosurg 1993;78:864–870
4 House WF, Hitselberger WW. Preservation of the facial nerve in acoustic tumor surgery. Arch Otolaryngol 1968;88:655–658
5 Ojemann RG. Management of acoustic neuromas (vestibular schwannomas) (honored guest presentation). Clin Neurosurg 1993;40:498–535
6 Samii M, Matthies C. Management of 1000 vestibular schwannomas (acoustic neuromas): the facial nerve—preservation and restitution of function. Neurosurgery 1997;40:684–694, discussion 694–695
7 Samii M, Matthies C. Management of 1000 vestibular schwannomas (acoustic neuromas): surgical management and results with an emphasis on complications and how to avoid them. Neurosurgery 1997;40:11–21, discussion 21–23
8 Samii M, Gerganov V, Samii A. Improved preservation of hearing and facial nerve function in vestibular schwannoma surgery via the retrosigmoid approach in a series of 200 patients. J Neurosurg 2006;105:527–535
9 Ransohoff J. Microsurgical anatomy of the brainstem surface facing an acoustic neuroma. Surg Neurol 1986;26:598 (Letter)
10 Rhoton AL Jr. Microsurgical anatomy of the brainstem surface facing an acoustic neuroma. Surg Neurol 1986;25:326–339 (Letter)
11 Rhoton AL Jr, Tedeschi H. Microsurgical anatomy of acoustic neuroma. Otolaryngol Clin North Am 1992;25:257–294
12 Moriyama T, Fukushima T, Asaoka K, Roche PH, Barrs DM, McElveen JT Jr. Hearing preservation in acoustic neuroma surgery: importance of adhesion between the cochlear nerve and the tumor. J Neurosurg 2002;97:337–340
13 Sameshima T, Fukushima T, McElveen JT Jr, Friedman AH. Critical assessment of operative approaches for hearing preservation in small acoustic neuroma surgery: retrosigmoid vs middle fossa approach. Neurosurgery 2010;67:640–644, discussion 644–645
14 Benecke JE Jr, Calder HB, Chadwick G. Facial nerve monitoring during acoustic neuroma removal. Laryngoscope 1987;97:697–700
15 Taoka T, Hirabayashi H, Nakagawa H, et al. Displacement of the facial nerve course by vestibular schwannoma: preoperative visualization using diffusion tensor tractography. J Magn Reson Imaging 2006;24:1005–1010
16 Gerganov VM, Giordano M, Samii M, Samii A. Diffusion tensor imaging-based fiber tracking for prediction of the position of the facial nerve in relation to large vestibular schwannomas. J Neurosurg 2011;115:1087–1093
17 Sampath P, Rini D, Long DM. Microanatomical variations in the cerebellopontine angle associated with vestibular schwannomas (acoustic neuromas): a retrospective study of 1006 consecutive cases. J Neurosurg 2000;92:70–78
18 Bae CW, Cho YH, Hong SH, Kim JH, Lee JK, Kim CJ. The anatomical location and course of the facial nerve in vestibular schwannomas: a study of 163 surgically treated cases. J Korean Neurosurg Soc 2007;42:450–454
19 Rand RW. Microneurosurgery. 3rd ed. St Louis: Mosby; 1985
20 Rand RW. Microsurgical anatomy of the brainstem surface facing an acoustic neuroma. Surg Neurol 1987;27:403(Letter)