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Position and Course of Facial Nerve and Postoperative Facial Nerve Results in Vestibular Schwannoma Microsurgery

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■ OBJECTIVE: **To investigate the variation in the position and course of the facial nerve (FN) in patients undergoing vestibular schwannoma (VS) microsurgery by the keyhole retrosigmoid approach and the relationship between FN position and postoperative facial results.**

■ METHODS: **The series consists of 100 patients who underwent VS microsurgery during a 5-year period in whom the position and course of the FN could be confirmed by direct stimulation. The course of the FN was classified into 4 patterns according to its position: anterior (ventral) surface of the tumor (A), anterior-superior (AS), anterior-inferior (AI), and dorsal (D).**

■ RESULTS: **The distribution of patterns was as follows: AS in 48 cases, A in 31, AI in 21, and D in zero. For tumors <1.5 cm, the AS pattern was most common (68.4%). For tumors ≥1.5 cm, the proportion of A and AI positions increased (31.4% and 25.5%). Significant differences were observed between position and course patterns of the FN and postoperative nerve results. Patients with AS and AI patterns had better House-Brackmann FN function compared with patients with the A pattern ($P < 0.05$). Moreover, in tumors >3.0 cm, the FN tended to adhere strongly to the tumor capsule, and postoperative facial deficits were more frequent ($P < 0.05$).**

■ CONCLUSIONS: **The AS pattern was most common for smaller VSs. The A position and course and adhesion of the FN to the tumor capsule were the 2 factors most strongly associated with worse postoperative FN result.**

INTRODUCTION

The aims of vestibular schwannoma (VS) microsurgery are safe tumor resection, hearing preservation when preoperatively socially useful, and preservation of facial nerve (FN) function. In recent years, operative results have improved significantly using dedicated microsurgical instruments and technologies, and, in particular, the incidence of FN palsy is quite low in the hands of expert skull base teams.[1-12] In general, during VS microsurgery, surgeons remove the tumor while confirming the position of the FN, the course of which is known to vary according to tumor size, site of origin, and degree of adhesion.[1-3,5,7-9,11,12] Accurate preoperative identification of the anatomic position and course of the FN is difficult even with current advances in magnetic resonance imaging (MRI) technology; the only method currently available is confirmation under microscope with repeated intraoperative FN stimulation. In this study, the associations of FN position and course patterns in VS and its adhesion to tumors and postoperative FN palsy were investigated in a series of 100 consecutive cases.

Key words
- Facial nerve
- Facial nerve adhesion
- Facial nerve position
- Facial nerve preservation
- Retrosigmoid approach
- Vestibular schwannoma

Abbreviations and Acronyms
A: Anterior
AAO-HNS: American Academy of Otolaryngology—Head and Neck Surgery
ABR: Auditory brainstem response
AI: Anterior-inferior
AS: Anterior-superior
D: Dorsal
EMG: Electromyography
FN: Facial nerve
HB: House-Brackmann
MRI: Magnetic resonance imaging
VS: Vestibular schwannoma

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MATERIALS AND METHODS

Subjects were 100 patients undergoing surgery for VS by the keyhole retrosigmoid approach between July 2010 and July 2015 (47 women and 53 men; mean age, 49.4 years; mean tumor size, 24.1 mm). Total or near-total (99%) or subtotal (90%) removal of the tumor was attempted in all cases and obtained in 90 cases, and the FN was anatomically preserved in 94 cases. According to the House-Brackmann (HB) scale,[13] a preoperative HB II–HB IV FN palsy was present in 2 cases. All procedures were performed by the senior author (L.M.) with intraoperative FN monitoring and intraoperative auditory brainstem response monitoring for hearing preservation in AAO-HNS class A or B cases.[14] The data obtained included patient age, tumor size, preoperative and postoperative FN function, and extent of adhesions between the FN and the tumor capsule.

The course of the FN was classified into 4 patterns according to its position (Figure 1): anterior (ventral) surface of the tumor (A), anterior-superior or ventral-cranial (AS), anterior-inferior or ventral-inferior (AI), and dorsal (D). In very large tumors, the patterns could not be fit completely, and the course in the vicinity of the internal auditory canal—where adhesions were the strongest and separation was most difficult—was evaluated.

Normal (HB I) facial function was present preoperatively in 98 patients. In addition, the FN was anatomically preserved at surgery in all but 4 of 98 cases. FN outcome was reported on the HB scale, and the results are recorded as early (approximately 7 days after surgery) and late (minimum 6 months after surgery).

Strong or less strong adhesion between the tumor and FN was evaluated during the procedure by the first author and was correlated with the maximum diameter of VS and results. The surgeon's impression had a major influence when evaluating the degree of adhesion of the FN to the tumor, as there is no scale for its classification. Less strong adhesion was defined as situations in which the FN could be separated from the tumor relatively easily with blunt dissection by dedicated microdissectors; strong adhesion was defined as situations in which it was difficult to separate the capsule from the nerve, requiring sharp dissection with microscissors.

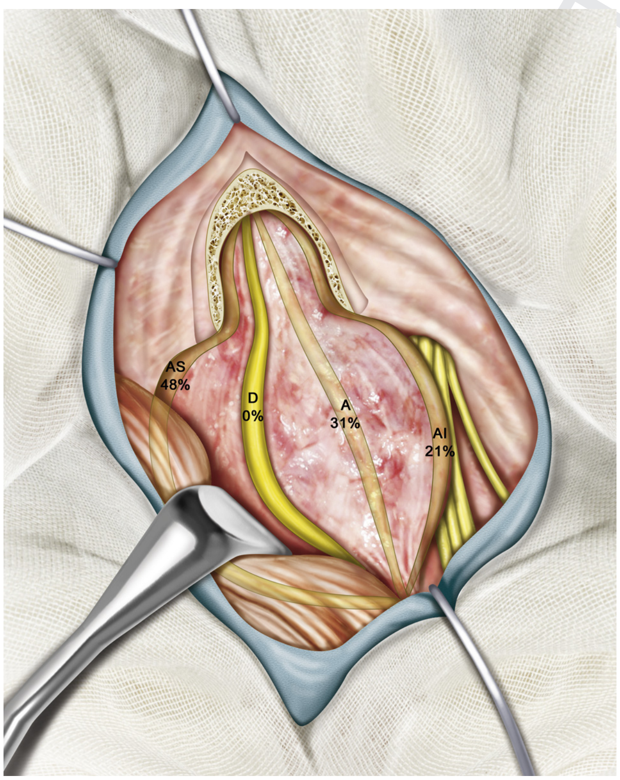

Figure 1. Possible position of facial nerve in 100 consecutive vestibular schwannomas. AS, anterior-superior; D, dorsal; A, anterior; AI, anterior-inferior.

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Determination of Tumor Size

All patients underwent MRI ≤1 month before admission. Tumor was measured in 3 spatial dimensions (on axial and coronal MRI section planes), and tumor size was estimated considering its main diameter, including the part of tumor extending into the internal auditory canal.

FN Function

FN function was assessed preoperatively (clinically and with electromyography [EMG]) and 1 week and ≥6 months postoperatively using HB classification (HB I, normal; HB VI, total paralysis).[9]

Audiologic Data

In patients selected for hearing preservation (AAO-HNS class A or B),[3] audiologic examinations were performed preoperatively and 1 week and 6 months postoperatively by pure tone audiometry, auditory brainstem response (ABR), and monosyllabic speech audiograms.

Intraoperative Procedures

Monitoring of FN and Cochlear Nerve. In all cases, FN EMG monitoring was used during all surgical procedures (Nimbus i-Care 100 intraoperative neurophysiologic monitoring; Newmedic division of Hemodia, Labège, France), with electrodes inserted in orbicularis oris and orbicularis oculi muscles. FN stimulation was performed with a monopolar (on surface of tumor) or bipolar (close to the nerve) stimulator, starting from ≥2 mm amp (on the capsule, for nerve course localization) to 0.3–0.05 mm amp (directly on the nerve, for confirmation of function).

Each patient selected for hearing preservation underwent ABR audiometry (Nicolet Viking III; VIASYS NeuroCare, Madison, Wisconsin, USA) the day before surgery. In the last 15 cases, we used ABR neuromonitoring evoked with CE-Chirp stimuli (Eclipse EP15 ABR system; Interacoustics A/S, Middelfart, Denmark).[15] According to AAO-HNS classification, 43 patients belonged to class A or B, with reproducible responses that allowed continuous intraoperative ABR monitoring of cochlear nerve.

Retrosigmoid Approach. All operations were performed by the retrosigmoid approach with the patient in lateral position.[16] A continuous lumbar drain was placed in larger tumors and was left in place for 3–4 days, for cerebellar detension during

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surgery and postoperative wound closure. The skin incision consisted of a slightly curved line extending 5–6 cm behind the ear, approximately 1 cm posteriorly to mastoid. Free pericranial flap was harvested for dural closure. The retrosigmoid-retromastoid lateral occipital bone was exposed, including superior and inferior nuchal lines.[16,17] A craniotomy approximately 3 cm^2 exposing sigmoid and transverse sinuses and the angle in between was performed. The retrosigmoid dura mater was opened in a semicircular shape, followed by lateral medullary cistern arachnoid opening for cerebellar detension by cerebrospinal fluid aspiration. After cutting the dura mater covering the roof of the internal auditory canal, the opening of the canal was performed with a 4-mm extra-coarse diamond burr or with a Sonopet Ultrasonic Aspirator (Stryker, Kalamazoo, Michigan, USA) with dedicated bone tips. When adequate detension of the cerebellar hemisphere is obtained, the tumor surface is exposed, with or without retraction, and the possible position of the FN is detected by using the stimulator.

According to Fukushima's technique,[16,17] a V-cut was usually performed, and debulking of the tumor was obtained with microscissors, microcurettes, bipolar forceps, Sonopet Ultrasonic Aspirator (62 cases, usually with maximum diameter >2 cm), and handheld lasers (51 cases) for vaporizing and cutting. Using standard microsurgical instruments (sharp dissectors, sickle knife, McElveen knife, stright and curved microscissors, ring and cup curettes), the tumor capsule was separated from brainstem and cranial nerves during continuous FN and—in selected cases—cochlear nerve monitoring. In small tumors (usually with maximum diameter <2 cm), it was possible to establish the specific vestibular nerve of origin of tumor (inferior or, less frequently, superior). However, the small number of cases in which there data were available did not allow us to determine a possible relationship with FN displacement. An arachnoid plane between tumor and nerves was usually present, especially in smaller tumors. Also, because of the small number of cases, it was impossible to evaluate whether the absence of a clear arachnoid plane had an influence on the FN displacement. Accurate hemostasis and tight dura mater closure using autologous harvested pericranial graft, hemostatics, and sealants were performed, and a fitted titanium net or the bone operculum was placed on the craniectomy with miniscrews.

Determination of Tumor Removal. The amount of tumor removed was assessed by surgeon opinion and by postoperative contrast-enhanced MRI performed within 1 week after surgery. The removal was classified as total (100%), near total (99%; millimeter-sized residual capsule frequently not detectable by enhanced MRI), subtotal (90%), and partial (<90%).

Statistical Analysis

For categorical analysis, χ^2 test was used to calculate differences in FN position, adhesion of tumor capsule to FN, postoperative FN results, and other clinical variables, with analysis of variance adjusted for tumor size and amount of surgical removal. The differences were considered very significant if $P < 0.01$, significant if $P < 0.05$, or not significant if $P > 0.05$.

RESULTS

The mean age of the entire cohort was 49.4 years (range, 15–80 years), and the average maximum diameter of tumor was 2.41 cm (range, 0.5–5.8 cm). In 96 cases (96%), the tumor extended and enlarged in the internal auditory canal; in 4 cases, the tumor was medial (without intrameatal extension). Hearing preservation was possible in 30 of 43 cases (69.8%) that preoperatively belonged to AAO-HNS class A or B. In these cases, the average maximum diameter of VS was 1.89 cm, and all patients had serviceable hearing (class A or B) postoperatively.

Brainstem edema associated with the interface of the tumor was observed on preoperative MRI in 9 cases. In 15 cases (15%), the tumor had ≥1 cystic components inside on MRI and confirmed by surgery. The mean age of patients with cystic tumors was 51.7 years (vs. 49 years for patients with solid type), the mean diameter was 3 cm (vs. 2.3), tight adhesion were present in 9 of 15 cystic cases (60%) versus 34 of 85 solid cases (40%). Preoperative hearing was socially useful in 3 cystic cases (20%) versus 28 solid cases (32.9%). Regarding FN results, at minimum 6-month follow-up, 100% of cystic cases were HB I versus 90.4% of solid cases. All these differences between cystic and solid VSs were not statistically significant.

Strong adhesion of capsule to FN was observed in 43 cases (43%). In these cases, the mean maximum diameter of tumor was 3.1 cm (vs. 1.9 cm of less adherent cases; $P < 0.05$). Among adherent cases, 9 (21.9%) were cystic versus 6 (10.5%) less adherent cases (P = not significant). Hearing preservation was possible in 5 of 9 (55.5%) adherent cases preoperatively class A and B and in 25 of 34 (73.5%) less adherent cases (P = not significant). In the whole series, total and nearly total removal was possible in 68 cases (68%), subtotal removal was possible in 25 cases, and partial removal was possible in 7 cases. In cases of subtotal or partial removal, residual capsule was left because of tight adhesion to FN and/or to brainstem.

Position and Course of FN, Mean Diameter of Tumor, and Mean Age

We did not find any relationship between the specific group of FN displacement and the difficulties with nerve location and detachment from tumor. The AS pattern (in which the FN ran ventrally and superiorly over the tumor capsule) accounted for 48 of 100 cases, the largest proportion of cases overall, followed by the A pattern in 31 cases and AI pattern in 21 cases; we did not observe a D pattern for position and course of FN (Table 1). The maximum diameter of the AS group was 2.29 cm, and the mean patient age was 52.3 years; for the A group, these were 2.52 cm and 50.5 years, respectively, and for the AI group, 2.57 cm and 40.3 years, respectively. These differences are not statistically significant with the exception of mean age; the difference is statistically significant ($P < 0.05$) on comparing the age of the AI group versus the other 2 groups (AS and A). Among the 15 cystic VSs, the FN had AS position and course in 7 cases (14.5%), A position and course in 4 (12.9%), and AI position and course in 4 (19%).

Categorized by tumor size, for VSs <1.5 cm, the position was AS in 13 of 19 cases (68.4%), A in 4 cases (21%), and AI in 2 cases (10.5%). For tumors 1.5–3.0 cm, the position was AS in 22 of

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Table 1. Position and Course of Facial Nerve: Differences in Mean Age, Mean Maximum Diameter of Tumor, and Presence of Cysts Among Subgroups

	Entire Series	AS	A	AI	D
Number of cases	100	48	31	21	None
Mean age, years	49.4	52.3	50.5	40.3*	
Maximum diameter, cm	2.41	2.29	2.52	2.57	
Cystic cases	15	7 (14.5%)	4 (12.9%)	4 (19%)	

AS, anterior-superior; A, anterior; AI, anterior-inferior; D, dorsal.
*Difference between mean age of AS and A groups versus AI group is statistically significant ($P < 0.05$).

51 cases (43.1%), A in 16 cases (31.4%), and AI in 13 cases (25.5%). For tumors >3.0 cm, the position was AS in 13 of 30 cases (43.3%), A in 11 cases (36.7%), and AI in 6 cases (20%; Table 2). For tumors <1.5 cm, the AS position was the most common, accounting for more than two thirds of cases. For tumors ≥1.5 cm, the proportion of A and AI patterns rose; in particular, when maximum diameter size was >3.0 cm, there was an increase in the proportion of patients with severely distorted courses, such as the AI pattern, in which the FN runs along the caudal side of the tumor capsule.

FN Early and Late Outcome According to HB Scale

Table 3 shows FN function according to the HB scale for each FN position and course approximately 1 week after surgery and at late follow-up examination (minimum 6 months). Except the 2 patients with a preoperative facial palsy, at the early evaluation, HB I patients accounted for 57 cases (58.2%), 30 of 47 (63.8%) of AS pattern, 16 of 30 (53.3%) of A pattern, and 11 of 21 (52.4%) of AI pattern. HB II patients accounted for 19 cases (19.4%), 11 cases (23.4%) of AS pattern, 3 cases (10%) of A pattern, and 5 cases (23.8%) of AI pattern. Patients assessed as HB III or worse accounted for 22 cases (22.4%), 6 cases (12.8%) of AS pattern, 11 cases (36.7%) of A pattern, and 5 cases (23.8%) of AI pattern.

At ≥6-month follow-up, HB I patients accounted for 90 cases (91.8%), 46 of 47 cases (97.9%) of AS pattern, 24 of 30 cases (80%) of A pattern, and 20 of 21 cases (95.2%) of AI pattern. HB II patients accounted for 1 case (2.1%) of AS pattern, 2 cases (6.7%) of A pattern, and 1 case (4.8%) of AI pattern. Patients assessed as

Table 2. Position and Course of Facial Nerve Classified by Tumor Size

Maximum Diameter, Number of Cases	AS	A	AI
<1.5 cm, 19	13 (68.4%)	4 (21%)	2 (10.5%)
1.5—3 cm, 51	22 (43.1%)	16 (31.4%)	13 (25.5%)
>3 cm, 30	13 (43.3%)	11 (36.7%)	6 (20%)

AS, anterior-superior; A, anterior; AI, anterior-inferior.

Table 3. Position and Course of Facial Nerve and House-Brackmann Postoperative Results in 98 Cases (Excluding 2 with Preoperative Facial Palsy)

	Total (98 Cases)	AS (47 Cases)	A (30 Cases)	AI (21 Cases)
HB-I 1 week after surgery	57 (58.2%)	30 (63.8%)	16 (53.3%)	11 (52.4%)
HB-II 1 week after surgery	19 (19.4%)	11 (23.4%)	3 (10%)	5 (23.8%)
HB-III or worse at 1 week	22 (22.4%)	6 (12.8%)	11 (36.7%)	5 (23.8%)
HB-I at ≥6-month follow-up	90 (91.8%)	46 (97.9%)	24 (80%)*	20 (95.2%)
HB-II at ≥6-month follow-up	4	1 (2.1%)	2 (6.7%)	1 (4.8%)
HB-III or worse at ≥6-month follow-up	4	—	4 (13.3%)	—

HB, House-Brackmann; AS, anterior-superior; A, anterior; AI, anterior-inferior.
*Difference between late outcome of facial nerve HB function of AS and AI groups versus A group is statistically significant ($P < 0.05$).

HB III accounted for 4 cases (13.3%), all with A pattern. There were no statistically significant differences in outcome for different FN positions and courses in terms of postoperative FN function except for the worst results of A pattern on the long-term follow-up compared with AS and AI subgroups ($P < 0.05$). Regarding the FN results between cystic and solid VSs, at minimum 6-month follow-up, 100% of cystic cases were HB I versus 90.4% of solid cases (P = not significant).

Adhesion Between Tumor and FN

Table 4 shows strong or low adhesion between the tumor capsule and FN in terms of course pattern and tumor size. Most VSs with a maximum diameter >3 cm had strong adhesions of capsule to FN.

In the entire series, strong adhesion was present in 43 cases: 21 of 48 (43.7%) of AS group, 13 of 31 (41.9%) of A group, and 9 of 21 (42.9%) of AI group. For tumors with maximum diameter <1.5 cm, 2 of 19 cases had strong adherence (10.5%): 1 case with AS and 1 with A position. For tumors 1.5—3.0 cm, 16 of 51 cases (31.4%) were strongly adherent; 8 (50%) had AS pattern, 5 had A pattern, and 3 had AI pattern. For tumors >3.0 cm, 25 of 30 cases (83.3%) showed strong adherence between capsule of VS and FN and/or brainstem. In 12 cases (48%), the FN had AS position and course, in 7 (28%), A position and course; and in 6 (24%), AI position and course. The higher incidence of strong adhesion in tumors with maximum diameter >3 cm is statistically significant ($P < 0.05$).

Strong adhesion was more frequent for larger tumors in all course patterns. In most cases, the site of strongest adhesion between tumor and FN was in the region of its entrance into the internal auditory canal or at the level of pontine origin in all position and course subgroups.

Postoperative FN Function (Late) and Tumor Adhesion to FN

A comparison of postoperative FN function in relation to capsule adhesion showed that strong adhesion had a significant effect on FN outcomes (Table 5). In 4 cases, the FN was embedded within the tumor capsule, resulting in worse postoperative result. At

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Table 4. Adhesion Between Tumor and Facial Nerve: Relationship Between Facial Nerve Position and Maximum Diameter of Vestibular Schwannoma

Size Subgroups, Number of Cases	Strong Adhesion	AS (48 Cases)	A (31 Cases)	AI (21 Cases)
	43 cases (43%)	21 (43.7%)	13 (41.9%)	9 (42.9%)
<1.5 cm, 19	2 (10.5%)	1 (50%)	1 (50%)	—
1.5–3 cm, 51	16 (31.4%)	8 (50%)	5 (31.2%)	3 (18.8%)
>3 cm, 30	25 (83.3%)*	12 (48%)	7 (28%)	6 (24%)

AS, anterior-superior; A, anterior; AI, anterior-inferior.
*The higher incidence of strong adhesion between tumor and facial nerve is statistically significant ($P < 0.05$) on comparing vestibular schwannoma with maximum diameter >3 cm versus smaller tumors.

6-month follow-up, HB-I FN function was observed in 33 (80.5%) of 41 strongly adherent cases (2 had preoperative facial palsy) versus 100% of cases with low adherence (Table 5).

Changes in FN Morphology

When the tumor was >3.0 cm, the FN tended to become thinned and flattened and to adhere to the tumor capsule more strongly.

DISCUSSION

The aims of VN microsurgery are safe and total or "near total" (99%) tumor resection, hearing preservation (when preoperative hearing is socially useful), and FN preservation (possibly HB I).[1-4,6-12,18-21] To obtain these results and minimize complications, detailed knowledge of anatomy, dedicated and innovative microinstruments, microsurgical training, and large experience are mandatory.[1-3,7,11,12,22-24] At the present time, in high-volume centers, the incidence of FN palsy is <10%.[4,6-10]

Table 5. Postoperative Late Facial Nerve Function and Tumor Adhesion to Facial Nerve in 98 Vestibular Schwannomas (Excluding 2 Cases with Preoperative Facial Palsy)

	Strong Adhesion (41 Cases)	Low Adhesion (57 Cases)
Mean maximum diameter (cm)*	3.1	1.9
Cysts inside tumor	9 (21.9%)	6 (10.5%)
Hearing preservation	5/9 cases (55.5%)	25/34 cases (73.5%)
HB-I at ≥6-month follow-up (90 cases)	33 (80.5%)	57 (100%)
HB-II at ≥6-month follow-up (4 cases)	4 (9.7%)	—
HB-III or worse at ≥6-month follow-up (4 cases)	4 (9.7%)	—

HB, House-Brackmann.
*Difference between mean maximum diameter of the 2 subgroups is statistically significant ($P < 0.05$).

Dizziness and reduced hearing are usually the first symptoms of VS; preoperative FN palsy is rarely present at admission (2% of our series). Therefore, preservation of FN function requires great attention and energy. The position and course of the FN is variable based on tumor size, tumor origin, and degree of adhesion; resection proceeds step by step confirming FN location, which may change during the debulking of the mass and the dissection of its capsule.

Preoperative assessment of the position and course of the FN is difficult even with sophisticated MRI. In small VSs, the course of the FN sometimes can be confirmed by MRI cisternography and diffusion tensor tractography.[3,12] With this method, Taoka et al.[12] preoperatively evaluated the position and course of the FN in 8 VSs; this was possible in 7 cases, and the course of the constructed tract agreed with intraoperative findings in 5 of them. In the other 2 cases, the tumor was large or cystic. Gerganov et al.[3] used diffusion tensor imaging–based fiber tracking in 22 patients with large VSs and reported that the position of the FN in relation to the tumor could be predicted in 91% of cases using this technique.

Particularly in large VSs, the FN often is displaced, compressed, and flattened and is strongly adherent to tumor capsule; sometimes, it is infiltrated or enfolded by the tumor. In these cases, it is difficult to confirm its position and course. The only affordable method available at the present time is the confirmation of its course with repeated intraoperative FN stimulations during tumor excision.[1,2,7-10] Usually, as previously described by other authors,[1,2,7] we perform several intraoperative FN stimulations, with a monopolar (on the surface of large VSs) and/or bipolar (directly on the nerve) stimulator, identifying the FN root exit zone and the FN position and course on the capsule of the tumor, confirming its function and possible dislocation during tumor debulking and capsule dissection. Continuous EMG of the nerve is always obtained too.

On considering the FN position and course in our series, the AS pattern (nerve on the ventral and cranial surface of the tumor capsule) was the most common (48%), followed by A (31%) and AI (21%) patterns (Table 1). FN course across the dorsal portion of the tumor (D pattern) has never been observed. The mean age of group AS and A patients (52.3 years and 50.5 years, respectively) is significantly higher than the mean age of AI group patients (40.3 years; $P < 0.05$), although we do not have an explanation for this difference. The position and course of the FN seems to change in relation to the size of VS: The mean maximum diameter of tumor was 2.29 cm in AS group, 2.52 cm in A group, and 2.57 cm in AI group, but these differences are not statistically significant. In particular, AS pattern accounted for 68.4% of cases of small VSs (maximum diameter <1.5 cm) versus 21% of A and 10.5% of AI patterns. For VSs measuring 1.5–3 cm, the frequency of AS decreases (43.1%), whereas A and AI patterns increased to 31.4% and 25%, respectively. For tumors having maximum diameter >3.0 cm, the position shifted to ventral surface (A pattern) in 36.7% of cases (Table 2). In addition, we observed a strong adhesion of tumor capsule to the FN in 43% of cases, especially in the region of its entrance into the internal auditory canal and at the level of pontine exit zone

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in all pattern subgroups. We observed a higher incidence of strong adhesion between tumor capsule and FN in large VSs (maximum diameter >3 cm; $P < 0.05$); no correlation with FN pattern was found (Table 4).

In a series of 356 cases, Sameshima et al.[7] observed that the FN was more frequently on the ventral-central surface of the tumor (corresponding to our A group), especially in small VSs. Also in their series, strong adhesion of FN to the tumor capsule was most closely associated with postoperative FN palsy.

In their series of 1006 VSs, Sampath et al.[11] observed a great variation in anatomic location and involvement of neurovascular structures in the cerebellopontine angle; in particular, FN most commonly ran across the anterior middle third of tumor (corresponding to our A group). This pattern was seen in 40.0% of cases with maximum diameter <2.5 cm, 40.2% in VSs 2.5–4 cm, and 39.8% in larger tumors (>4 cm maximum diameter), followed by the anterior superior third (corresponding to AS group) in 33.5%, 33.2%, and 32.7% of cases.

On analyzing their 163 cases, Bae et al.[1] classified FN position and course into 4 groups: 1) ventral and superior surface of tumor (AS in our classification), 2) ventral and central surface (our A group), 3) ventral and inferior surface (our AI group), and 4) dorsal surface (D). Similar to our findings, they reported that the FN 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%. In contrast to our series, in VSs with maximum diameter <2.0 cm, the ventral and central surface pattern was most common (65.2% of cases), whereas for larger tumors (>2.0 cm), the ventral and superior surface was the most common (59.3%). As in the series of Sameshima et al.[7] and in contrast to our observations, the FN position and course increasingly shifted to the rostral side with increasing tumor size.

Using the retrosigmoid approach, Rand[5] reported that the dorsal pattern (FN running on the operator's side of the tumor) has an incidence of 7%–9% of cases. However, the frequency of this position and course seems to be quite lower—0.3%–2.6%.[1,7,11] In our series, we never observed the D pattern of FN.

Regarding the postoperative FN outcome, 91.8% of the patients of our series were HB I at minimum 6-month follow-up. Considering the results in relation to the different position and course of the FN (Table 3), AS and AI groups had the best long-term results (HB I 97.9% and 95.2%, respectively, vs. only 80% of patients of group A; $P < 0.05$). In relation to the degree of adhesion between FN and tumor capsule (Table 5), all cases with low adhesion were HB I at minimum 6-month follow-up, whereas 19.5% of cases with strong adherence were HB-II or worse. Similar to the series of Sameshima et al.,[7] there was no difference with respect to postoperative FN function among different subgroups of pattern.

Based on these data, we prefer to perform a "nearly total" (99%) removal in large VSs with severe adhesion between tumor and a stretched and flattened FN, which is more difficult to preserve, leaving a millimeter-sized remnant of capsule along the course of the nerve. Close clinical and MRI follow-up is warranted in these cases.

CONCLUSIONS

When performing VS microsurgery, attempts should be made to preserve hearing acuity (if socially useful before surgery) and to identify the position and course of the FN for preserving its function. Because accurate identification of the course of the FN on preoperative MRI is unreliable, surgical manipulation must be careful and precise, using appropriate microinstruments, frequent intraoperative nerve stimulations, and continuous EMG monitoring.

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