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Original Article

What Really Decides the Facial Function of Vestibular Schwannoma Surgery?

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Objectives. To find the main cause of facial nerve dysfunction in vestibular schwannoma (VS) surgery and review the prognosis of facial function in relation to tumor size, preoperative facial function and surgical approach.

Methods. We reviewed the surgical outcome of 134 patients with VS treated in our department between 1994 and 2008. All patients included in the study had postoperative facial paralysis after surgical management of their VS. There were 14 women and 7 men. The mean age was 48.5 years, with a mean follow-up period of 57 months.

Results. Twenty-one patients (sustained facial palsy, 4; newly developed facial palsy, 17) had facial nerve paralysis after surgery: ten patients in large VS and eleven patients in small VS. In large VS group, 4 patients had facial nerve function of HB grade II, 3 patients had HB grade III, and 3 patients had HB grade IV. In small VS group, 9 patients had HB grade II and 2 patients had HB grade IV. Middle cranial fossa approach rather than translabyrinthine approach for the preservation of hearing, led to facial nerve deterioration and the patients who had facial nerve paralysis perioperatively, had resulted in permanent facial paralysis.

Conclusion. The tumor size in VS is certainly one of the most important prognostic factors. However, VS tumor size alone should not be considered a unique prognostic indicator. The surgical approach used, which may be related to tumor size, based on the surgeon's experience, can be a deciding factor, and the status of the facial nerve injured by the tumor can influence postoperative facial nerve function.

Key Words. *Vestibular schwannoma, Facial nerve*

INTRODUCTION

The surgical outcome of vestibular schwannoma (VS) is primarily determined by complete tumor removal and preservation of neurologic function. With the advent of the operative microscope in 1960 (1), the mortality and morbidity rates in the surgical excision of VS have declined and, consequently, preservation of the facial nerve has become an essential aspect of VS surgery. Although facial nerve outcomes are now excellent in over 90% of patients in virtually all published series (2), and anatomical and functional preservation of the facial nerve have become routine with experienced physicians (3), facial paralysis always remains a major concern, and preservation of the facial nerve can still be challenging, especially in cases of large VSs.

It is well-known that the size of the VS is a major predictor of facial nerve anatomical and functional preservation (4-6). While other factors, including age of the patient, previous treatment, intraoperative monitoring of the facial nerve, and surgical approach, have all been implicated as prognostic factors of facial nerve function (7), from our experience, to preserve the nerve and its function, correct identification of the course of the facial nerve adjacent to the tumor, and overcoming the variable displacement patterns of the facial nerve and surgical techniques, including surgical approach, are also important factors in deciding the outcome of facial function.

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Whatever size the tumor is, all patients are informed of possible surgical complications and the unpredictable prognosis of facial paralysis beyond limited reversibility of good facial nerve function, because preservation of facial nerve function is complex, due to extreme stretching and vulnerability, regardless of VS size. Further, anatomical nerve integrity does not necessarily mean a functional facial nerve.

In the present study, we tried to find the cause of facial nerve dysfunction in VS surgery and review the prognosis of facial function in relation to many factors; we also discuss ways to protect the facial nerve in patients diagnosed with a large VS.

MATERIALS AND METHODS

Patient population

This study was approved by the institutional review board at the investigators' institution. Data were obtained from our tertiary referral center acoustic tumor database originally developed to study practice trends from 1994 to 2008. In total, 134 consecutive patients underwent surgical removal of VS. Of them, in 50, the VSs were >20 mm in their largest extra-meatal diameter, and in 84, the VSs were ≤20 mm.

A retrospective chart review of the patients was performed. Patient documentation, pre- and postoperative neuroradiological data, operative reports, and follow-up data were reviewed. The following information relevant to the study was recorded: patient age, gender, initial signs, tumor size, neurological status at presentation, surgical complications, and changes in facial function.

Group A (50 patients with large VS, tumor size >20 mm)

The mean age was 47.9 years (range, 14 to 70 years); there were 15 men (30%) and 35 women (70%). The left side was involved in 23 cases and the right in 27. Eleven patients had giant tumors (>40 mm), six patients had large tumors (31-40 mm), and 33 patients had moderately large VS tumors (21-30 mm). Two patients were treated with staged operations, due to the large size of their tumors. Two patients had undergone radiosurgical treatment previously.

Group B (84 patients with small VS, tumor size ≤20 mm)

The mean age was 48.9 years (range, 11 to 73 years); there were 32 men (38%) and 52 women (62%). The left side was involved in 43 cases and the right in 41. Fifteen patients had small tumors (1-10 mm) and 69 patients had medium tumors (11-20 mm).

Evaluation of tumor size

The size of the tumor was determined based on linear planimetric measurements according to international criteria (8), and only the largest extra-meatal diameter was used. The portion of tumor located inside the internal auditory canal (IAC) was not included in the measurement, but tumors located wholly inside the IAC were included in small tumors.

Evaluation of facial nerve function and hearing levels

Preoperative and postoperative facial nerve function was assessed according to the House-Brackmann scale (9) and was checked by follow-up over 1 year. Pre- and postoperative hearing data were recorded using Academy of Otolaryngology-Head and Neck Surgery (AAO-HNS) criteria, including the four-frequency pure tone average (PTA) at 500 Hz, 1 kHz, 2 kHz, and 3 kHz, and the word recognition score presented at 40 dB hearing level (HL) at phonetically balanced maximum. Pre- and postoperative hearing was classified according to the guidelines published by the Committee on Hearing and Equilibrium of the AAO-HNS (10).

Surgical procedure and postoperative care

The surgical approach was selected on the basis of the location and size of the tumor and the presence or absence of serviceable hearing. Other factors, such as age, anatomy, and contralateral hearing levels, were also taken into consideration. If hearing preservation was not a goal, a translabyrinthine approach was usually used. The middle cranial fossa approach was selected in case of laterally-located, small tumors, with serviceable hearing levels. However, for the final selection of surgical approach, serviceable hearing was decided by the patient, after careful counseling by a neuro-otologist.

All the translabyrinthine approach and middle cranial fossa approach procedures were performed in an identical fashion. Facial nerve monitoring (NIM-Response 2.0 Nerve Integrity Monitoring System, Medtronic Xomed Surgical Products Inc., Jacksonville, FL, USA) was used to identify and confirm the function of the facial nerve intraoperatively.

The surgical technique for the translabyrinthine approach was that described by House, with minor modifications (11, 12). The facial nerve identified at the labyrinthine segment, as the unchanged landmark of location of facial nerve regardless of tumor size or tumor shape, widening the exposed window of the lateral IAC at the transverse crest. The superior and inferior vestibular and cochlear nerves were separated from facial nerve and disarticulated from the lateral canal. Along the exposed traveling of the facial nerve, the mass was debulked and removed. At the same time, tumor was dissected at the pontomedullary junction with medial to lateral direction, continuing the identification of the facial nerve. Frequent facial nerve identification and stimulation to monitor the response were performed throughout the procedure. Finally, the tumor was debulked and dissected completely while keeping the direct vision of the facial nerve. Once the entire tumor was removed, the dura was approximated with sutures, and abdominal fat was packed into the dura opening for a watertight closure.

Middle cranial fossa procedures were performed in selected cases. The patient's head was placed in a Mayfield head rest and a Greenberg retractor system was used to provide enhanced exposure. The middle meningeal artery was routinely divided to allow placement of the retractor blade over the petrous ridge. To avoid the injury of the cochlea and cochlear nerve, widening of internal auditory canal was performed around the perigeniculate ganglion with little damage of cochlea and identification of cochlear nerve at the middle of internal auditory canal was preferred with sharp dissection from tumor using microscissors or microknives (13, 14). From the proximal tympanic portion to IAC portion, the facial nerve was exposed and decompressed.

The tumor was completely removed in all cases except two. Computed tomography (CT) with a bony window was performed within 1 day of the operation. Completeness of tumor resection, facial nerve function, including sign and symptoms, audiograms, if needed, and imaging materials were used to evaluate the patient's postoperative condition.

Outcome measurement and statistical analyses

Outcome measurements included complete removal of the tumor, facial nerve function, audiograms, imaging materials, including postoperative CT scans, magnetic resonance imaging, photography, and recorded videography, and the surgical complication rate. The chi-squared and Fisher's exact tests were used to compare outcomes. A difference at a probability level ≤ 0.05 was deemed to indicate statistical significance.

RESULTS

Group A

The mean size of the VS was 29.9 mm. The mean time to follow-up assessment was 14.5±8.6 months (median, 12.1). The most frequent neurological deficit at presentation was hearing disturbance, observed in all 50 patients; 18 patients (36%) had complete hearing loss. Average pure tone audiometry was 78.3 dB on the diseased side (scale-out was considered as a hearing level of 120 dB). Tinnitus and vestibular dysfunction were noted in 36 (72%) and 32 patients (64%), respectively. Five patients had preoperative facial nerve paralysis; HB grade II in four patients, grade III in one patient. One patient presented with hemifacial spasm. Abducent nerve palsy was present in one patient (2%) and four patients (8%) had low cranial nerve dysfunction.

Tumor removal using a translabyrinthine approach was conducted in 48 patients and a middle cranial fossa approach in two patients. The VSs were totally removed in 48 of the group A patients. Incomplete tumor removal led to staged operations in two patients with very large tumors extending to the brainstem, and facial function was normal after the final operation in these patients.

The anatomical integrity of the facial nerve was preserved in 48 patients (96%). In the other two patients (4%), the nerve was found to be extremely flaccid and atrophic, and restoration of facial nerve continuity was created with harvested sural nerve. Three patients had complete facial paralysis immediately after surgery, including those with loss of the anatomical integrity of the nerve. Despite the preservation of the nerve in one patient, complete facial nerve paralysis continued and hypoglossal-facial anastomosis was performed 3 months later. Follow-up examination showed that facial nerve function recovered to HB grade IV in three patients.

The most common complication was cerebrospinal fluid (CSF) leakage, either from the wound or rhinorrhea. Of the 50 procedures, 8 patients (16%) had a CSF leak requiring surgical repair. Among them, 7 patients had undergone translabyrinthine approach and 1 patient had undergone middle cranial fossa approach. Two patients developed intracranial hemorrhage and one patient had postoperative wound infection (Table 1).

Group B

The mean size of the VS was 12.8 mm. The mean time to follow-up assessment was 13.5±9.3 months (median, 11.8). The most frequent neurological deficit at presentation was hearing disturbance, observed in 75 patients. Five patients (5.9%) had com-

Table 1. Comparisons of clinical presentation and surgical outcomes between two groups

	Group A	Group B
No. of patients	50	84
Mean age of patients (years)	47.9	48.9
Clinical presentation		
Hearing disturbance	50 (100)	73 (87)
Average PTA (dB)	78.3	51.3
Complete hearing loss	18 (35)*	5 (5.9)*
Tinnitus	36 (72)	49 (58)
Vestibular dysfunction	32 (64)	38 (45)
Facial nerve paralysis	5 (10)*	2 (2.4)*
Abducent nerve paralysis	1 (2)	0
Lower cranial nerve dysfunction	4 (8)	0
Mean tumor size (mm)	29.9	12.8
Surgical technique		
Translabyrinthine approach	48 (96)	60 (71)
Middle cranial fossa approach	2 (4)	24 (29)
Postoperative facial nerve paralysis	10 (20)	11 (13)
HB grade II	4 (8)	9 (11)
HB grade III	3 (6)	0
HB grade IV at last follow-up	3 (6)	2 (2.3)
Mean HB grade (immediate/final)	1.76/1.48	1.58/1.19
Incomplete tumor removal	2 (4)	0
Postoperative complication	11 (22)	8 (9.5)
CSF leakage requiring repair	8 (16)	6 (7.1)
Intracranial hemorrhage	2 (4)	0
Meningitis	0	2 (2.3)
Wound infection	1 (2)	0

Values are presented as number (%).
PTA: pure tone average; CSF: cerebrospinal fluid.
*$P<0.05$ according to the Fisher's exact test.

plete hearing loss. Average pure tone audiometry was 51.3 dB on the diseased side (scale-out was considered as a hearing level of 120 dB). Tinnitus and vestibular dysfunction were noted in 49 (58%) and 38 patients (45%), respectively. Two patients had preoperative facial nerve paralysis, HB grade III in both. One patient presented with hemifacial spasm. No patient had low cranial nerve dysfunction.

Tumor removal using a translabyrinthine approach was conducted in 60 patients and a middle cranial fossa approach was used in 24 patients. The VSs were totally removed in all group B patients.

The most common complication was CSF leakage, either from the wound or rhinorrhea. Of 84 procedures, six patients (7.1%) had a CSF leak requiring surgical repair. Among them, 2 patients had undergone translabyrinthine approach and 4 patients had undergone middle cranial fossa approach and two patients (2.3%) developed meningitis (Table 1).

Details of patients who had facial nerve paralysis after surgery

Twenty-one patients had facial nerve paralysis after surgery: 10 in group A and 11 in group B.

Facial paralysis in group A

The mean preoperative HB score was 1.5. Four patients had preoperative facial nerve paralysis and six patients had normal facial function. All had immediately impaired facial function after surgery (mean HB score, 3.6), and their final mean HB score was 2.9. Immediate and complete facial paralysis indicated a poor prognosis for facial function at last follow-up. Four (80%) of five patients who had preoperative facial weakness had facial paralysis after surgery and one patient had restored facial function after surgery.

The average tumor size was 32.6 mm (range, 22 to 60 mm). Tumor removal using a translabyrinthine approach was conducted in eight patients and a middle cranial fossa approach in two. In group A, all the patients who had been operated on using a middle cranial fossa approach had postoperative facial nerve paralysis.

At last follow-up, four patients had facial nerve function of HB grade II, three patients had HB grade III, and three patients had HB grade IV. No patient had complete facial paralysis (Table 2).

Facial paralysis in group B

The mean preoperative HB score was 1. All had normal facial function preoperatively and had immediately impaired facial function after surgery (mean HB score, 3.27), and their final mean HB score was 2.36. Fifteen patients had immediate facial nerve paralysis after surgery and eleven patients (73%) had not recovered their facial function completely at the last follow-up. Average tumor size was 12.7 mm (range, 5 to 18 mm). Tumor

Table 2. Summary of the patients who had postoperative facial nerve paralysis

Patients	Sex/age	Facial nerve function		Preop audiometry (PTA/WRS)	Postop audiometry (PTA/WRS)	Tumor size	Surgical approach	Complication
		Preop HB	Postop HB					
Group A	F/14	1	2	SO	SO	60	Translab	CSF leakage
(n=10/50, 20%)	F/53	1	2	58/24	SO	22	Translab	-
	M/48	2	3	15/100	15/100	22	MCF	-
	M/33	1	4	33/100	SO	25	MCF	CSF leakage
	M/63	3	4	SO	SO	25	Translab	-
	F/59	1	2	SO	SO	40	Translab	-
	F/48	1	4	SO	SO	37	Translab	-
	F/45	2	2	64/8	SO	33	Translab	-
	F/62	1	3	118/15	SO	34	Translab	-
	F/49	2	3	59/5	SO	28	Translab	
Average	Mean age, 44.4	1.5	2.9	82.7/25.2	109.5/10	32.6	-	2/10 (20%)
Group B	F/38	1	2	39/62	SO	10	MCF	-
(n=11/84, 13.1%)	F/51	1	2	53/78	SO	15	Translab	-
	M/59	1	2	43/88	49/88	15	MCF	-
	F/50	1	4	24/98	39/100	5	MCF	-
	M/43	1	2	18/100	23/100	15	MCF	CSF leakage
	F/53	1	2	66/0	SO	10	Translab	-
	F/46	1	2	10/94	20/94	5	MCF	Meaningitis
	M/58	1	2	66/24	SO	17	Translab	-
	F/54	1	2	76/28	SO	15	Translab	-
	M/53	1	2	28/88	54/55	15	MCF	CSF leakage
	F/70	1	4	76/14	SO	18	Translab	-
Average	Mean age, 52.3	1	2.36	45.4/61.3	82.3/39.7	12.7	-	3/11 (27%)

PTA: pure tone average; WRS: word recognition score; SO: scale-out; CSF: cerebrospinal fluid; MCF: middle cranial fossa.

removal using a translabyrinthine approach was conducted in five patients and a middle cranial fossa approach in six.

The anatomical integrity of the facial nerve was preserved in all patients. At last follow-up, nine patients had facial nerve function of HB grade II and two patients had HB grade IV. None of the patients had complete facial paralysis (Table 2).

DISCUSSION

The surgical results associated with the resection of large VS have steadily improved over the past four decades. The final results for patients from whom large tumors were removed are measured by several factors: morbidity and mortality statistics, completeness of resection, and postoperative neural function. As surgical techniques and individual physician's experiences have improved, the expectation of preservation of facial function has increased (15).

As tumor size increases, however, facial nerve preservation is increasingly difficult (16). An important finding of our study is that other factors, even if they are related to tumor size, also exist.

First, a surgical technique using a middle cranial fossa approach, in an attempt at hearing preservation in patients with levels of serviceable hearing, can lead to facial nerve deterioration. Although hearing preservation is largely dependent on the surgeon's technique, decision making, and availability of refined supermicrosurgical instruments, factors such as experience, skill, and determination are very difficult to measure and statistically compare between surgeons (17).

Our data show a 62.5% (15/24 patients) hearing preservation rate in all attempted tumors, but of those patients who underwent hearing preservation surgery for VS, 33% (8/24 patients) of them suffered facial nerve dysfunction. That is, the middle cranial fossa approach is a more dangerous technique, and it is statistically significantly (chi-square test) more common to injure the facial nerve than when using a translabyrinthine approach (facial nerve paralysis rate, 12%; 13/108 patients). Many authors had reported no difference in facial nerve outcomes between VS surgical techniques (18, 19). However, in our experience, some limitations of the middle fossa approach for complete VS tumor removal lead to more common nerve injury, including the limited posterior fossa approach, the unfavorable position relative to the facial nerve, and the limited surgical field due to temporal lobe retraction.

In cases of huge VS, a reliable method is to find the facial nerve at the fundus of the internal auditory canal before the mass is debulked and removed because it is impossible to find the facial nerve at the brainstem and separate it from the tumor capsule, which is indented in the brainstem (20).

Second, perioperative facial dysfunction can lead to persistent facial sequelae. Among the patients who had preoperative facial dysfunction due to VS (n=7), four patients had facial nerve paralysis after surgery. Immediate, complete facial paralysis after surgery indicates a poor prognosis for facial nerve function. There were no patients with delayed facial paralysis, but in a significant number of the patients who had facial nerve paralysis immediately after surgery, the result was permanent facial paralysis (72%, 21/29 patients). Of these, eight patients (postoperative HB grade II in 5, III in 3 patients) recovered full facial function 3 6 months after surgery.

In the comparison between the groups, we found that the tumor size influenced the clinical presentation with regard to facial function as well as hearing dysfunction, tinnitus, vestibular dysfunction, and lower cranial dysfunction. Preoperative complete hearing loss was commonly found in patients with large VS (statistically significantly so by Fisher's exact test). Postoperative complications were also more frequent in large VS than in small VS, but not statistically significantly so.

According to our data, VS tumor size is certainly one of the most important prognostic factors. However, tumor size alone must not be considered to be a unique prognostic indicator. The surgical approach used, which may be related to tumor size, based on the surgeon's experience, can be a deciding prognostic factor, including facial nerve function, postoperative complications, and completeness of tumor removal. Also, the status of the facial nerve, injured directly or indirectly by the tumor, can influence the destiny of postoperative facial nerve function.

In conclusion, preservation of facial nerve function in VS surgery is complex, due to extreme stretching and vulnerability, regardless of VS size. The tumor size in VS is certainly one of the most important prognostic factors. However, VS tumor size alone should not be considered a unique prognostic indicator. The surgical approach used, which may be related to tumor size, based on the surgeon's experience, can be a deciding factor, and the status of the facial nerve injured by the tumor can influence postoperative facial nerve function.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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