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Vestibular schwannoma treatment : patients' perceptions and outcomes

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Chapter 7

Surgery for large vestibular schwannoma: residual tumor and outcome

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Abstract

Objective: To evaluate clinical outcome with regard to the amount of residual tumor after surgery for large vestibular schwannoma.

Patients: Between the period of January 2000 and December 2005 a total of 51 large vestibular schwannoma tumors with extrameatal diameter of 2.6 cm or greater (mean 32 mm; median 30 mm; range 26-50 mm) were operated using the translabyrinthine approach. The extent of the resection was intraoperatively estimated as complete, near and subtotal. The amount of residual tumor was measured and the shape and localization was scored on gadolinium-enhanced MR imaging. Correlation between intraoperative and MRI assessment was performed using the Fisher's exact test. Potential growth of residual tumor was documented with frequent MRI follow-up. Postoperative facial nerve function was classified according to the House-Brackmann classification.

Results: Complete resection was performed in 26% of the patients, near-total resection in 58% and subtotal resection in 16%. MRI showed residual tumor in 46% of patients (mean, 16.7 mm; SD, ± 8, range, 5-36 mm). Postoperative facial nerve function was House-Brackmann Grades I-II in 78% of the patients. The intraoperative assessment of near-total resection did not correlate with postoperative MRI ($p = 0.25$). Postoperative MRI showed either no residual tumor or residue that should actually have been classified as a subtotal resection. After a follow-up of 4 years (49 mo; mean, 48 mo), 94% of patients did not show changes on MRI.

Conclusions: Tumor control with good facial nerve function could be obtained in most patients. Intraoperative assessment did not correlate with the amount of residual tumor on postoperative MRI. Objective documentation with postoperative MRI to measure the extent of removal is therefore mandatory.

Introduction

The outcome of vestibular schwannoma (VS) surgery is mainly determined by the extent of tumor removal and preservation of neurological function. Complete tumor removal carries an increased risk of facial nerve paresis, especially in large tumors (1,2). To preserve facial nerve function and maintain quality of life (QoL), the surgeon may leave some tumor in situ. The completeness of tumor removal in surgical literature is usually reported in three groups: complete, near or subtotal. Near-total (or partial) resection is defined as a residue of less than 5% of the original tumor size and subtotal resection as more than 5% (3). Objective assessment of the actual extent of removal documented with postoperative gadolinium-enhanced magnetic resonance imaging (MRI) scans, however, is scarcely provided (4-10). Intraoperative assessment of the extent of tumor removal lacks objectivity. The lack of objective postoperative MRI data on tumor resection has consequences for interpreting the total outcome of surgical treatment. For instance, postoperative facial nerve function should be significantly better when tumor is deliberately left behind.

In 2001 the consensus meeting on VS in Tokyo proposed a system for reporting surgical results in VS (3). Regarding the amount of residual tumor, it was stated that the extent of tumor removal should be confirmed on postoperative gadolinium-enhanced MRI scans. The size of the residue should be described in two perpendicular diameters and with its subsequent localization: within the meatus, outside the meatus along the cranial nerves and at the brainstem or the cerebellum.

In the present study we report on the surgical results after translabyrinthine surgery for large vestibular schwannomas (≥ 2.6 cm) focused on residual tumor. The amount of residual tumor as (intraoperatively) estimated by the surgeon and the amount of residual tumor as documented on postoperative MRI scans were compared. When residual tumor was present, the location and size was further classified according to Kanzaki et al. (3). Moreover, correlation between facial nerve function and presence or absence of residual tumor and regrowth in time was studied.

Materials and Methods

Patients

Between the period of January 2000 and December 2005, a total of 51 VS tumors with extrameatal diameter of 2.6 cm or greater were operated using the translabyrinthine approach. Patients with NF2 or incomplete follow-up were excluded from the analysis. One patient was lost to follow-up which resulted in 50 patients (17 men and 33 women) who were retrospectively studied. The mean age of the patients was 49 ± 14 years (range, 19-75 yr). The completeness of removal was peroperatively estimated as complete; near-total or partial removal, in which less than 5% of the initial tumor was left in situ, and subtotal removal, in which more than 5% of the initial tumor was left in situ (3).

Preoperative and postoperative facial nerve function was classified according to the House-Brackmann (H-B) classification (11). Guidelines of the AAO-HNS Committee on Hearing and Equilibrium were used to classify preoperative hearing status (12). All 50 patients preoperatively had non-serviceable hearing on the tumor ear (Classes C and D according to the American Academy of Otolaryngology-Head and Neck Surgery (AAO-HNS)).

Preoperative tumor size

Preoperative tumor size was defined using the largest extrameatal diameter on an axial 1.5 T MRI T1-image with gadolinium enhancement (Magnevist®, Bayer, Utrecht, The Netherlands). The following group classification was used: intrameatal tumors, small tumors (1-10 mm), medium (11-25 mm), large (26-40 mm) and extra large (> 40 mm) (13). The mean tumor size was 32 mm ± 6.0 mm (range, 26-50 mm). There were 45 patients (90%) with large tumors and 5 patients with extra large tumors (10 %).

Residual tumor

The amount of residual tumor was evaluated on postoperative 1.5 T MRI (Gyroscan®, Philips Medical Systems, Eindhoven, The Netherlands) scans using axial T1-weighted sequences with a slice thickness of 1 millimeter, with gadolinium enhancement, and fat suppression. According to our standard postoperative protocol, a “baseline” MRI was performed in all patients at a mean of 11 months ± 7 months (range, 2-39 mo) after surgery. This protocol requires a first MRI scan between 6 and 12 months after surgery. Of the 50 patients, 46 (92%) were scanned within this required interval.

During our follow-up program, a second scan (mean 29 ± 9 mo postsurgery; range, 15-51 mo) and a third scan (mean, 49 ± 17 mo postsurgery; range, 28-94 mo) were performed to observe possible changes in enhancement or growth of residue. All MRI data were evaluated by the first author and the neuroradiologist (FB) blinded for the intraoperative assessment data of the surgeons. The largest diameter of the entire enhancement (in millimeters) in any of the axial 1-mm T1-images was measured on the baseline postoperative MRI scan. The surface (in square millimeters) of the preoperative tumor and postoperative residual tumor was also measured on axial MRI scans.

When interpreting MRI scans after VS surgery, it is now recognized that slight linear high-signal enhancement in the internal auditory canal (IAC) corresponds to dura mater inflammation or postoperative scar tissue, whereas nodular enhancement in the IAC or cerebello-pontine angle (CPA) is suspected for recurrent or residual tumor (14,15). Therefore, the enhancement in the IAC and CPA was analyzed for a linear and / or nodular aspect or pattern. Enhancement pattern corresponding with dura mater inflammation or scar tissue were not classified as residual tumor. The exact location of the enhancement was then assessed according to the Kanzaki classification of residual tumor: residual tumor within the meatus, outside the meatus along the nerves, or at the brainstem or cerebellum (3). The location of the largest part ("bulk") of the enhancement was used and classified according to the classification of Kanzaki. The differences within groups and between groups were calculated using the Student's t-test, Chi square test, and the Fisher's exact test was used to assess correlations. Statistical significance was set at $p < 0.05$ (SPSS software version 14.0 for Windows).

Results

The surgical team intraoperatively estimated that in 13 (26%) of 50 cases a complete removal was performed and that in 37 patients (74%), tumor was left in situ. Of these 37, in 29 (58%) patients, a near-total removal was achieved, whereas in 8 (16%) patients a subtotal removal was performed. Regarding the mean preoperative tumor size, there was no significant difference between complete, near and subtotal groups (resp. 31, 31 and 34 mm; $p = 0.3$).

In 27 (54%) patients of the 50 patients, enhancement was observed on the first postoperative gadolinium-enhanced T1-weighted MR images (mean, 11 ± 7 months; range, 2-39 months). For these 27 patients, the mean diameter of the enhancement observed on MRI measured 15.7 mm (SD, ± 8; range, 5-36 mm). Of these 27 patients, 14 patients had an enhancement with a linear-nodular configuration, and in 9 patients, an enhancement with a single nodular configuration was observed. In 4 patients, the enhancement had a slight linear configuration (Figure 1A).

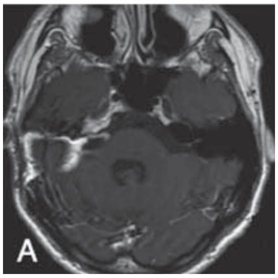

Figure 1A. Postoperative contrast-enhanced T1 MRI axial scan showing linear enhancement in the IAC.

Of the 14 patients with a linear-nodular configuration, the largest part of the enhancement was located near the brainstem (according to the classification of Kanzaki). Of the 9 patients with a single nodular configuration, the largest part of the enhancement on MRI was observed just outside the meatus along the facial nerve. In 4 patients with a slight linear configuration, the enhancement was localized in the IAC. In these patients the enhancement was not classified as residual tumor. A second and third MRI follow-up scan showed an unchanged linear configuration for these patients.

As a result, 23 patients (46%) of the 50 cases had MRI findings corresponding with residual tumor (mean, 16.7 mm; SD, ± 8, range 5-36 mm).

All of these 23 patients were intraoperatively classified as either a near-total or subtotal removal. There was no residual tumor observed in patients intraoperatively classified as complete removal (Table 1). Correlations between the intraoperative estimation and the postoperative MRI results showed that when the surgeon estimated the removal as either complete or incomplete (near- or subtotal), this observation significantly correlated with the MRI results ($p = 0.01$). The intraoperative assessment of the surgeon regarding the presence of residual tumor may therefore be considered as reliable.

Table 1. Postoperative MRI assessment of the completeness of tumor removal.

MRI	Intraoperative assessment			
	Complete	**Near-total**	**Subtotal**	
Residu	0	15	8	23
No residu	13	14	0	27
Total	13	29	8	50

The group that was surgically qualified as a near-total resection (n = 29) had residual tumor on MRI in 15 patients (mean, 14.6 mm; SD, ± 7.5; range, 5-34 mm), whereas in 14 patients no residual tumor was observed. In all 8 subtotally operated patients, residual tumor was present on MRI (20.75 mm; SD, ± 7.7; range, 10-36 mm). The mean diameter of the residual tumor on MRI between the group classified as near-total and the group classified as subtotal was not significantly different (p = 0.2; Figure 1B).

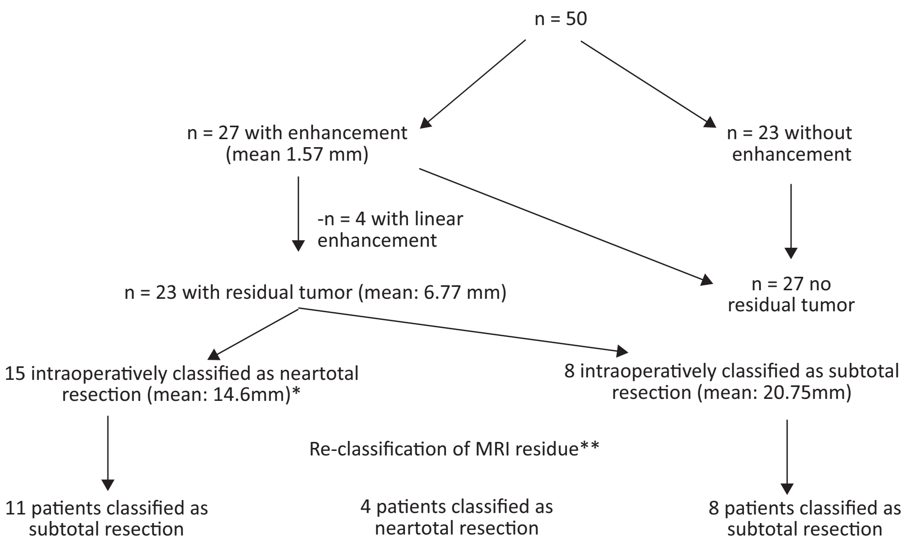

Figure 1B. Flow chart demonstrating the intraoperative and postoperative MRI reclassification of the amount of residual tumor (*p = 0.2, no significant difference in tumor size between groups) (**according to the 5% definition: postoperative tumor size (mm^2) / preoperative tumor size (mm^2) x 100%).

A near-total removal (or partial removal) is defined by tumor resection, of which less than 5% of the initial tumor is left in situ. A subtotal removal is defined by tumor resection, of which more than 5% of the initial tumor is left in situ (3). Of the 23 patients with residual tumor on MRI, the surface area (in square millimeters) of the residual tumor was compared to the preoperative surface area of the initial tumor. If the amount of residual tumor on MRI was less than 5% of the initial tumor size, then the residual tumor was reclassified as near-total resection. If the amount of residual tumor on MRI was more than 5% of the initial tumor, the residual tumor was reclassified as subtotal resection (Figure 1B). The MRI results show that of the 15 tumors that were intraoperatively estimated as a near-total resection, 11 tumors were in fact subtotal resections according to the 5% definition. Only 4 tumors that were intraoperatively assessed as a near-total resection were actually classified as near-total resection on the postoperative MRI (according to the 5% definition; Table 2; Figure 1C and D). All of the 8 tumors that were intraoperatively estimated as a subtotal resection were classified as subtotal resection on postoperative MRI (according to the 5% definition; Table 2; Figure 1E and F). The intraoperative assessment regarding near-total resection did not correlate significantly with postoperative MRI results (p = 0.25). The estimation of the surgeon regarding a near-total removal can therefore not be considered as reliable.

Table 2. MRI classification of residual tumor for the near- and subtotal (sub)groups.

MRI measured residu	**Intraoperative assessment**		
	Near-total	**Subtotal**	**Total**
Near-total	4*	0	4
Subtotal	11*	8	19
Total	15	8	23

* p = 0.25.

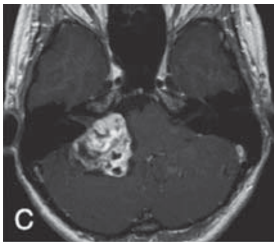

Figure 1C. Preoperative contrast-enhanced T1-weighted MRI axial scan showing a tumor with a diameter of 43 x 30 mm.

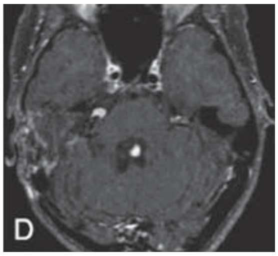

Figure 1D. Postoperative contrast-enhanced T1-weighted MRI axial scan showing residual tumor with a diameter of 10 x 6 mm. The resection was classified as near-total both intraoperatively and after reclassification on MRI.

Facial nerve outcome

Facial nerve outcome in relation to completeness of removal is presented in Table 3. In 39 patients (78%), H-B Grades I to II were achieved at an average of 12 months (SD, ± 4 mo) (range, 2-24 mo) postoperatively. In 11 patients (22%), there were H-B Grades III to IV. In 2 of these patients, the facial nerve was anatomically not intact, and facial nerve reconstruction was performed. In 1 patient, a sural nerve graft was directly interposed, and in the other a (delayed) facial-hypoglossal nerve transfer with direct coaptation of the intratemporal part of the facial nerve was performed (16). Finally, in both patients, H-B Grade III was achieved. There were no patients with H-B Grades V to VI.

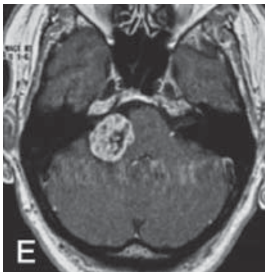

Figure 1E. Preoperative contrast-enhanced T1-weighted MRI axial scan showing a tumor with a diameter of 28 x 20 mm.

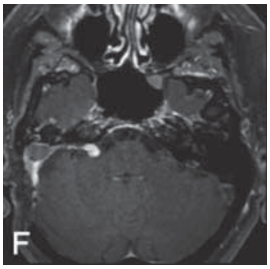

Figure 1F. Postoperative contrast-enhanced T1-weighted MRI axial scan showing a residual tumor with a diameter of 15 x 8 mm. The resection was classified as subtotal both intraoperatively and after reclassification on MRI.

In the near-total and subtotal operated group, a relatively high number of patients have a favorable facial nerve outcome (H-B Grades I-II) when compared with patients with complete resections, although this difference was not statistically significant ($p = 0.4$; Table 3). In our series, facial nerve outcome did not correlate significantly to tumor size ($p = 0.6$).

Table 3. Facial nerve outcome according to completeness of removal (n = 50).

	Complete	Near-total	Subtotal	
Grades I-II	9*	22*	8*	39
Grades III-IV	4	7	0	11
Grades V-VI	0	0	0	0
Total	13	29	8	50

* p = 0.4.

In Table 4, facial nerve outcome is presented in relation to residual tumor on MRI. Facial nerve function H-B Grades I to II was equally distributed in the residual tumor group as in the group without residual tumor on MRI. An unfavorable facial nerve outcome (H-B Grades III-IV) was mainly found in patients without residual disease (n = 8) when compared to patients with residual tumor (n = 3). This difference was, however, statistically not significant (p = 0.17). Facial nerve results did not significantly differ between near or subtotal resections when controlling for age or tumor size (p = 0.06).

Table 4. Facial nerve function in relation to residual tumor on MRI (n = 50).

	Grades I-II	Grades III-IV	Grades V-VI	
Residu	20	3*	0	23
No residu	19	8*	0	27
Total	39	11	0	50

*p = 0.17.

MRI documented growth of residual tumor

In 40 of 50 patients, a second follow-up MRI was performed (mean, 29 mo; SD, ± 9; range, 15-51 mo). In 10 of the 50 patients, there was no indication for a second MRI because the initial resection was estimated as complete and the first MRI showed no residual tumor. Of the 40 patients, 23 had residual tumor on the first MRI, and the other 17 had no residual tumor on the first MRI. Twenty patients with residual tumor on the first MRI could be followed on a second MRI, and 3 were lost to follow-up due to death (n = 2; both not VS related), and 1 patient refused follow-up imaging. For these 20 patients with residual tumor on first MRI, 18 showed no change on the second MRI. In 2 patients, outgrowth of residual disease was observed at a mean of 36 months after surgery (SD, ± 9; range, 30-42 mo). In these patients, the residual disease had a linear-nodular configuration and was located at the brainstem (according to the Kanzaki classification). One patient was lost to follow-up before a third MRI scan could be made. In the remaining 17 residual tumor patients, a third MRI scan could be performed (mean, 49 mo; SD, ± 17; range, 28-94 mo), of which 16 showed no change. One patient clearly demonstrated outgrowth at 28 months postoperatively after an initial subtotal resection. The residual disease had a single nodular configuration that was located just outside the meatus and along the facial nerve. In the 17 patients who had no residual tumor on the first MRI, no growth could be detected on the second MRI.

As a result MRI documented outgrowth of residual tumor was observed in 3 (6%) of the 50 patients and after a follow-up of 4 years.

Postoperative complications

As shown in Table 5, postoperative complications occurred in 15 patients. There were no deaths related to the TL surgery, and most complications were transient. Cerebrospinal fluid (CSF) leakage was most frequently observed (n = 10), and most of these patients were treated with a lumbar drain. Three of these had to be treated for bacterial meningitis. In 5 patients, transient neurological complications occurred such as peroneal nerve apraxia, ataxia, or transient cranial nerve paresis.

Table 5. Postoperative complications (n = 15)*.

Complication	No. of patients
CSF leakage treated with lumbar drainage	8
CSF leakage treated with revision surgery	1
CSF leakage treated conservatively	1
Transient neurologic dysfunction	5
Bacterial meningitis	3
Postoperative hematoma requiring surgical drainage	2
Decubital ulcers	2
Sigmoid sinus thrombosis	1
Acute Respiratory Distress Syndrome	1

* Some patients experienced more than 1 complication.

Discussion

This study evaluated the results of surgical treatment of large VS with a focus on the amount of postoperative residual tumor and facial nerve outcome. The preoperative surgical strategy was to obtain complete tumor removal in all cases. This strategy was intraoperatively abandoned when strong tumor adhesions with brainstem and/or cranial nerves were encountered. In these instances, the surgeon decided to leave some tumor remnant behind so as not to jeopardize cranial nerve function. Overall, this surgical strategy resulted in removal that could be divided in 3 groups. Complete resection was obtained in 26% of the patients. In the 74% of patients in which tumor was left in situ, 58% was classified as near-total resection and 16% as subtotal resection. Interestingly, contrast-enhanced MRI 1 year postoperatively showed residual tumor in only 46% of patients. MRI did not show residual disease in the group that was surgically judged as complete resection. Apparently, in this group, the surgeon could reliably estimate whether the removal was complete or incomplete. All of the tumor remnants in the subtotal group were detected on MRI. Only the surgical assessment in the near-total group did not match the postoperative MRI images. Surprisingly, in approximately half of the patients in the near-total resection group, tumor remnants could not be dectected on MRI. This remained so on follow-up imaging. Surgical assessment in the near-total resection group in this respect was therefore too pessimistic.

Compared to MRI documentation, in about the other half of the tumors that were intraoperatively estimated as near-total resection, the amount of residual tumor should have been classified as subtotal resection. The drawback of this comparison is the 2-dimensional assessment of the preoperative tumor and postoperative residual tumor. A comparison of tumor volumes would have been more accurate, but such data could not be generated from our MRIs (17). However, we feel that our main conclusion will not be majorly affected by this drawback.

We hypothesize that in approximately half of the patients with near-total resections, postoperative tumor regression may have taken place. A possible explanation might be postoperative tumor necrosis after devascularisation. Residual remnants have been shown to be relatively avascular in VS managed with staged tumor resection (18).

At the consensus meeting on VS (2001), it was proposed that the intraoperative assessment of the extent of removal lacks objectivity, and that residual tumor should be documented with MRI. Sofar, the surgeon's estimation of completeness of tumor removal still holds as the gold standard in the recent literature and not the objective gadolinium-enhanced MRI documentation. For instance, both Lanman et al. (8) and Briggs et al. (6) reported an extent of resection up to 96%. In these studies, it was not clearly mentioned whether postoperative MRI assessment was performed. More recently, others did use postoperative imaging. Unfortunately, a clear picture of the amount of residual tumor was not provided. In addition, imaging methods were not clearly described, and time intervals between surgery and imaging were not given (9,19-21).

Compared to other reports on the surgical treatment of large tumors, we achieved comparable facial nerve outcome (78%; H-B Grades I-II) (18-24). The size of the tumor and the surgeon's experience are pre-operative predictors for postoperative facial nerve function. The outcome of facial nerve function in our series appeared not to be related to initial tumor size. Moreover, no significant difference in facial nerve outcome was found between the subtotal or near-total resection groups. When residual tumor was left behind, facial nerve outcome was more favorable. This relationship was, however, not statistically significant. Park et al. (22) reported a preserved facial nerve outcome in 78% of cases after surgery for large VS and found an inverse correlation between facial nerve preservation and the extent of removal. Bloch et al. (23) reported favorable facial nerve outcome (H-B Grades I-II) in 81% of patients after incomplete VS resection. Postoperative MRI in their series showed that 20% of near-total and 80% of subtotally operated patients had visible residual disease. According to the authors, the absence of residual tumor in the subtotal resection group was caused by tumor regression due to devascularisation of the tumor remnants. However, the surgeon's intraoperative assessment regarding the extent of the removal might have been too pessimistic, as was the case in our series. Raftapoulos et al. (24) also performed MR imaging after surgery for large VS in order to assess their rate of tumor removal and found residual tumor in 31% of cases with preserved facial nerve function in almost all patients. In our opinion, preservation of facial nerve function is not primarily related to tumor size. We think that the vulnerability of the facial nerve is especially related to the course it takes over the tumor capsule, whether the nerve is stretched out and whether it is anatomically recognizable or only by stimulation.

To clearly distinguish actual residual tumor from dura mater inflammation or postoperative scar tissue, we described the configuration of the residue. In 4 of the 27 patients, a linear configuration was observed within the IAC. Because of this configuration, we did not consider it as residual tumor. The dural enhancements observed in these 4 patients remained unchanged even after a follow-up of more than 3 years. The other (nodular) configurations corresponded with residual tumor and were localized near the brainstem or just outside the meatus along the facial nerve.

Recurrence was defined as MRI-documented outgrowth of residual tumor and was observed in 3 patients (6%) after a follow-up of more than 4 years. Of these patients, 2 had initially been operated subtotally, and 1 patient near-total. Two patients underwent reoperation mainly because their growing residue was linear-nodular and localized near the brainstem.

The presence or absence of tumor remnants after surgery is a major outcome measure. In this series, it appears that adequate intraoperative assessment of the extent of resection was very difficult, especially in the near-total resected tumors. Postoperative MRI to objectively measure the extent removal is therefore needed.

Conclusion

In this study, the preoperative surgical intention was to achieve complete tumor removal in large VS with preservation of facial nerve function. Magnetic resonance imaging-documented residual disease was observed in 46% of patients. In most patients, the residual tumor had a linear-nodular configuration and was located near the brainstem. Tumor control could be obtained in 94% of the patients. Recurrence mostly occurred in patients after subtotal resections with a linear-nodular configuration of the residual tumor localized at the brainstem. Postoperative facial nerve function was H-B Grades I to II in 78% of the patients. A trend between absence or presence of residual tumor and facial nerve function was observed; however, statistically not significant. Intraoperative assessment of the amount of residual tumor did not correlate well with the amount of residual tumor on the MRI scan. Postoperative residual tumor documentation should always be performed to provide a basis for assessment of recurrent disease and for interpretation of functional outcome.

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