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Comparison of Postoperative Outcomes in Cystic Versus Solid Vestibular Schwannoma in a Multi-institutional Cohort

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Abstract

Objective: Cystic vestibular schwannomas (cVSs) have more variable and less favorable clinical outcomes after microsurgical resection compared with solid VS (sVS). This study compares the preoperative presentation and postoperative outcomes between cVS and sVS.

Study Design: Retrospective cohort study.

Setting: Two tertiary skull base referral centers.

Methods: Consecutive adult patients who underwent VS resection from 2016 to 2021 were included. Univariate and multivariate analyses compared differences in baseline symptoms and postoperative outcomes between cVS and sVS.

Results: There were a total of 315 patients (64% female; mean age, 54 yrs) and 46 (15%) were cystic. cVS were significantly larger than sVS (maximum diameter, 28 vs. 18 mm, $p < 0.001$) and had higher rates of dysphagia and dysphonia preoperatively ($p < 0.02$). cVSs were more likely to undergo translabyrinthine resection (76 vs. 50%, $p = 0.001$) and have a higher rate of subtotal resection (STR) compared with sVS (30 vs. 13%, $p = 0.003$). At latest follow-up, fewer cVS achieved good facial nerve (FN) outcome (House-Brackmann [HB] I/II) (80 vs. 90%, $p = 0.048$). Subanalysis of cVS and sVS matched in tumor size, and surgical approach did not show differences in the rate of STR or FN outcomes (HB I/II, 82 vs. 78%, $p = 0.79$).

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Conclusion: In this large multi-institutional series, cVSs represent a distinct entity and are characterized by larger tumor size and higher incidence of atypical symptoms. Although cVSs were more likely to undergo STR and portend worse FN outcomes than sVSs, this may be due to their larger tumor size rather than the presence of the cystic component.

Keywords

Acoustic neuroma; Adherent; Cystic; Facial nerve function; Microsurgical resection; Vestibular schwannoma

INTRODUCTION

Vestibular schwannomas (VSs) are the most common benign primary intracranial tumor of the cerebellopontine angle. Estimates of the prevalence of VS are approximately 1 in 2000 adults (up to 1 in 500 in the elderly population, age ≥70 yrs) with an incidence around 1 to 2 per 100,000 (up to 21 per 100,000 person-years in the elderly).[1] Cystic VSs (cVSs) have an incidence ranging from 4 to 23%.[1-3] Although the pathophysiology of macrocystic degeneration is not clearly defined in VS, cVSs exhibit faster rates of tumor growth causing compressive effects on surrounding structures including the brainstem and facial nerve (FN) secondary to cyst expansion, resulting in rapid onset of neurological symptoms.[4-7]

With the widespread use and availability of high-resolution magnetic resonance imaging (MRI), an increasing fraction of VSs are managed with close observation using serial imaging. However, large VS, cystic tumors, or those associated with atypical symptoms or lower cranial neuropathy attributable to brainstem compression are indications for surgical intervention.[8,9] The current role for stereotactic radiosurgery in cVS is controversial in the literature, with some studies demonstrating similar, if not better, tumor control in cVS patients versus their solid VS (sVS) counterparts.[10,11] However, at many other institutions including ours, stereotactic radiosurgery is typically deferred to treat cVS because of the risk of worsening cerebral edema from cyst expansion and less predictable outcomes. Thus, microsurgical resection remains the treatment of choice for patients with cVS with the goals of tumor control, decompression of the posterior fossa and brainstem, symptom relief, and prevention of disease progression.[12,13]

Previous studies on cVS demonstrated variable results in rates of postoperative FN function as well as the extent of tumor resection.[5,8,9,14-19] More recently, prioritizing anatomic preservation of cranial nerve function while maximizing tumor resection in cVS, especially in larger tumors, has been employed more frequently.[20] This strategy often leads to less-than-complete, subtotal tumor resections (STR). Patients who underwent STR could have significantly higher rates of tumor regrowth compared with those who underwent gross total resection (GTR).[20]

However, despite the need for aggressive surgical management, several features of cVS increase perioperative morbidity and risk of cranial nerve injury even in the hands of experienced skull base surgeons. One of the challenges in resecting cVS is to dissect the cystic component from surrounding structures, as there are often significant peritumoral adhesions to the FN and brainstem secondary to inflammatory reactions from cystic tumor

degeneration. Prior studies on cVS are frequently from single institutions accumulated over long study duration, resulting in increased heterogeneity of patient populations, practice patterns, and surgical techniques. To address these limitations, we conducted a large, contemporary, multi-institutional study from two high-volume acoustic neuroma programs to compare postoperative outcomes between cVS and sVS. Furthermore, to further eliminate potential confounders, we also reported subanalysis of cVS and sVS matched in both tumor size and surgical approach.

METHODS

Retrospective chart reviews were conducted of a total of 315 patients at two tertiary academic skull base referral centers who underwent VS resection from September 2016 to May 2021. This study was approved by each institution's respective Institutional Review Boards (The Ohio State University Wexner Medical Center and University of California, San Diego). Patients were included in this study if they were treated for a sporadic VS and were older than 18 years. Patients with predisposing genetic conditions (e.g., neurofibromatosis type 2) were excluded. All MRI images were screened by a board-certified neuroradiologist, neurotologist, and skull base neurosurgeon. A cVS was defined as a tumor containing one or more cystic components where the combined total cystic diameter was over 50% of the maximum mean tumor diameter on MRI. Patient demographics, tumor size, surgical approach, extent of resection, and postoperative outcomes were compared between cVS versus sVS. Tumor size was calculated as the diameter in the largest dimension on the most recent preoperative MRI, which included both the internal auditory canal as well as cerebellopontine angle tumor components. Preoperative, immediately postoperative (1–2 d postoperatively), and long-term (≥6 mo) cranial nerve function was recorded for all patients. FN function was quantified using the House-Brackmann (HB) grade I through VI. Good FN function was defined as having an HB score of I/II. Postoperative vestibular function testing (videonystagmography, vestibular evoked myogenic potential, video head impulse test) was not routinely completed in either cohort.

Univariate analyses of cVS versus sVS were completed using chi-square tests. Multivariate analyses for predictors of postoperative FN function were conducted with all statistically significant univariate predictors. For size/approach-matched subanalysis, cVSs that underwent translabyrinthine or retrosigmoid approaches were size matched with sVS by maximal diameter at time of surgery (88% matches were within 2 mm, 100% were within 4 mm). All size matches were completed within a 10% margin. Only one cVS patient underwent middle cranial fossa resection and thus was not included in the matched analysis. All percentages were calculated within the subgroup analysis (within cVS vs. sVS cohorts with complete data points, respectively). All statistical calculations were conducted with Stata 17.0 (College Station, TX).

RESULTS

A total of 315 patients were included (mean age, 51 ± 13yrs, 64% female). The mean follow-up duration was 17.4 months (standard deviation [SD], 10; range, 6–59 mo). The mean values of the follow-up time for cVS and sVS were 17.6 months (SD, 10.1) and 16.2

months (SD, 9.7), respectively ($p = 0.4$). Seventy-seven percent of patients had follow-up 1 year or more for assessment of postoperative outcomes, specifically FN function. Patient demographics and preoperative characteristics are listed in Table 1. Representative examples of MRI findings from an sVS and a cVS that are matched in maximum tumor diameter are shown in Fig. 1.

Cystic VS Outcomes

Forty-six (15%) patients had cVS. Cystic tumors were significantly larger at presentation compared with sVS (mean maximum tumor diameter, 2.8 vs. 1.8 cm, $p < 0.001$). Patients with cVS were also more likely to have symptoms associated with lower cranial nerve dysfunction of the glossopharyngeal, vagus, and hypoglossal nerves compared with sVS. Specifically, these included dysphonia (2 vs. 0%, $p = 0.02$) and dysphagia (4 vs. 0.3%, $p = 0.01$). No differences in preoperative FN function, nor the presence of dizziness or tinnitus, were observed between the two cohorts.

Postoperatively, cVS had significantly higher rates of subtotal tumor resection (STR) compared with sVS (30% STR vs. 13% STR, $p = 0.003$, Table 2). Compared with sVS, patients with cVS were more likely to undergo translabyrinthine craniotomy (76 vs. 50%, $p = 0.001$) and less likely to undergo middle cranial fossa approach for tumor resection (2 vs. 25%, $p = 0.001$).

In the immediate postoperative period (defined as 1–2 d postoperatively), cVS and sVS patients demonstrated similar FN function, with 78% cVS patients exhibiting good FN function defined as having an HB grade of I or II. By comparison, 86% of sVS had HB grade I or II immediately postoperatively ($p = 0.16$). At the latest follow-up, however, cVS had worse FN function than sVS (80% cVS had HB I/II vs. 90% of sVS, $p = 0.048$). Furthermore, cVS patients also had higher rates of dysphagia (20 vs. 8%, $p = 0.01$) that persisted even at long-term follow-up, although the number of patients is small (cVS 9% [N = 4] vs. sVS 0.6% [N = 2]). No differences were noted at either short-term or long-term follow-up in dizziness and tinnitus symptoms.

Predictors of Postoperative FN Outcomes

We further examined clinical predictors of FN function in solid and cVS both in the short-term and at more than 12-month follow-up time. In the immediate postoperative period, FN outcomes were significantly correlated with tumor size and surgical approach. Specifically, compared with patients with good FN function (HB grades I or II), patients with poor FN function (HB grade ≥ III) had larger tumors (2.6 cm vs. 1.8 cm, $p = 0.001$) and were more likely to have undergone tumor resection via the translabyrinthine approach (75 vs. 51%, $p = 0.02$).

At the most recent follow-up (mean duration, 17.4 mo; range, 6–59 mo), both tumor size and surgical approach were again significant predictors of good FN function (Table 3, $p < 0.01$). In addition, cVS demonstrated worse long-term FN function compared with sVS. In a multivariate model controlling for tumor size, cystic morphology, and surgical approach, tumor size and cystic morphology did not significantly impact FN outcome, whereas

surgical approach remained significantly predictive of good FN function (retrosigmoid odds ratio [OR], 4.2; 95% confidence interval [CI], 1.2–14.7; $p = 0.02$; vs. translabyrinthine).

Size- and Surgical Approach-Matched cVS Versus sVS Postoperative Outcomes

To eliminate potential confounding variables such as tumor size and surgical approach, we further characterized the relationship between the presence of cystic change and FN outcomes by performing subanalysis of cVS and sVS patients matched in tumor size and surgical approach. A total of 90 patients were included (45 cVS/sVS matched pairs), all of whom underwent either translabyrinthine (35 matched pairs) or retrosigmoid approach (10 matched pairs, Fig. 2). There were no significant differences in age or sex (Table 4, $p > 0.05$). Tumor size was not significantly different in the translabyrinthine (30.6 vs. 30.2 mm, $p = 0.86$) and retrosigmoid groups (19.1 vs. 19.3 mm, $p = 0.9$). Furthermore, there were no differences in postoperative FN outcomes at either the immediate or recent postoperative period ($p > 0.05$). In addition, no differences were noted in the rate of GTR (63 vs. 60% for translabyrinthine approach,$p = 0.81$; 90 vs. 100% for retrosigmoid approach, $p = 0.31$). In the translabyrinthine resection cohort, cVS patients had higher rates of postoperative tinnitus at latest follow-up (81 vs. 21%, $p < 0.001$).

DISCUSSION

Compared with sVS, patients with cystic tumors typically present with larger tumor size and have more rapid onset of symptoms related to the rapid and unpredictable macrocystic degeneration that often occurs.[6,15,18,19,21] Our data are consistent with the literature, where patients with cVS had a mean maximum tumor diameter of 28 mm, significantly larger than their solid counterparts (a mean maximum tumor diameter of 18 mm). We also demonstrate that cVSs have a higher incidence of symptoms related to lower cranial nerve dysfunction such as dysphonia or dysphagia, which are considered atypical for VSs and are likely attributed to the large tumor size and cystic component.[9,19] These may be related to the rapid cystic enlargement that exert significant mass effect on nearby intracranial structures compared with the relatively slow growth of solid tumors at a rate of 1 to 2 mm per year, which allows the brain parenchyma to accommodate tumor expansion.[22] In addition, elevated extracellular matrix remodeling due to aberrant protease activation in the VS tumor microenvironment could also lead to increased tumor inflammation and repeated hemorrhage within the tumor, further contributing to the rapid growth and increased morbidity of cVS.[8]

Although cystic tumors were historically associated with worse FN outcomes,[6] recent studies have begun to question this traditional dogma.[23-25] These studies argue that differences in outcomes between cVS and sVS are likely secondary to differences in tumor volume rather than the presence of the cyst. In our cohort, we demonstrate trends toward worse FN outcomes in the immediate postoperative period between sVS and cVS, where good HB scores were achieved in 78% of cVS and 86% of sVS, respectively. This was better demonstrated by the statistically significant long-term differences in FN function, where 90% of sVS patients achieve good FN function versus 80% of cVS patients. In our data, this discrepancy was likely due to cVS patients with worse long-term FN outcome versus most

sVS patients, who improved in their long-term FN function. Compared with the existing literature, which focuses primarily on a single time point for follow-up, we demonstrate in our data that cVS patients trended toward worse outcomes even at their first postoperative follow-up appointments, which has important implications for FN rehabilitation and patient counseling.[23] It may be possible that during dissection of cystic tumors, there is an increased likelihood of traction injury to the surrounding cranial nerves (facial and cochleovestibular) as the cystic tumors are inherently more adherent. Therefore, tumors that were subtotally resected because of the presence of adhesions were associated with higher rates of long-term FN dysfunction, as demonstrated in our study. Further studies looking at changes in long-term FN outcomes in cVS patients are needed.

Importantly, cVSs are usually larger than their solid counterparts at presentation, which presents a possible confounding variable.[9,23,25] Xie et al. demonstrated that when cVS and tumor size were considered simultaneously, size of the tumor was a much more significant factor in determining FN outcomes.[26] We demonstrate similar findings in our data, where tumor size consistently predicted postoperative FN outcomes. Our data also demonstrate that once the cVS cohort is size matched and approach matched to the sVS cohort, no differences in postoperative FN outcomes are noted, possibly suggesting that appropriate preoperative surgical approach planning can mitigate some of the expected poorer outcomes expected with the larger tumors, as is consistent with the previous literature.[23]

Another important factor in consideration of postoperative FN outcomes is the extent of tumor resection. Increased vascularity in cVS and greater adherence to the arachnoid plane and FN can make tumor dissection difficult.[7] Our multi-institutional cohort demonstrates that the incidence of GTR is lower in cVS than sVS (70 vs. 86%).[7] Some recent studies have countered these findings, demonstrating no differences in GTR rates despite similar FN outcomes in cVS versus sVS. [24,25] However, Han et al.[23] reported GTR rates of 33% (cVS) versus 46% (sVS), whereas Almefty et al.[25] reported 70% (cVS) versus 78% (sVS); both were lower than our cohort.[23,25] At our institution, the management goal is to achieve gross tumor resection while balancing the patient's quality of life by preserving the integrity of the FN. When a near or STR was performed, the decision was made intraoperatively, rather than preoperatively, to leave the smallest remnant of tumor and preserve nerve function.

Our findings are consistent with the study by Tang et al.,[24] who reported no statistically significant difference between cVS versus sVS with similar GTR rates to our cohort but with results approaching significance (76 vs. 86%, $p = 0.07$). At the same time, in our cohort, we demonstrate no differences between FN function based on extent of resection (good FN function in GTR, 90 vs. 82%, $p = 0.08$). Thus, one proposed cause for the worse FN functions in the cVS cohort despite similar rates of GTR could be secondary to traction injury on the nerve during resection. Our findings suggest that even with preoperative intent for total resection in cVS, intraoperative findings including peritumoral adhesions and larger tumor size can make GTR more difficult. This is further supported by the evidence that this difference is much less in our size- and approach-matched cohort. Based on our own experiences and results in the literature, we extensively counsel patients with cVS regarding less-than-total tumor resection and risks of cranial nerve dysfunction such as FN palsy. We

further advocate that patient education on postoperative outcomes and morbidities should be implemented in every case, but especially in those with cVS.

Previous studies have also suggested that cyst location, thickness, and even markers of inflammation in the local tumor microenvironment may contribute to ease of microsurgical resection as well as clinical outcomes.[6,26-29] Our data provide multi-institutional validation that additional factors beyond the presence of a macrocystic component might be more significant contributors to predicting FN function postoperatively.

Finally, our multi-institutional cohort includes over 315 patients over a 5-year period (averaging 63 patients per year). This is a significantly larger cohort than that in previous studies comparing cVS and sVS, including the retrospective analysis by Han et al.,[23] which includes 220 patients between 2007 and 2017 (average of 20 cases per year). Recent studies have demonstrated that larger-volume acoustic neuroma programs may significantly decrease postoperative adverse outcomes compared with smaller-volume counterparts, with the risk-defining threshold of 25 cases per year.[30] Thus, our research provides critical insights to these postoperative outcomes with our large, contemporary multi-institutional cohort compared with the existing literature.

The optimal treatment strategy for cVS remains an area of debate and active clinical research. Data from high-volume gamma knife centers have shown that stereotactic radiosurgery (SRS) remain a viable option for patients with cVS and achieve good rates of tumor control that are similar to sVS.[10,11,31] Our centers, like many other academic VS centers around the country, prefer upfront microsurgical resection as the first-line treatment of cVS, largely owing to the unpredictable nature of cVS growth and the likelihood of significant compressive symptoms should the cyst suddenly enlarge after nonsurgical treatment. This may represent some degree of inherent selection bias, and additional studies comparing SRS and surgery for cVS should be completed in the future. Evidence from the literature also suggests that intratumoral cysts may behave differently from peritumoral cysts.[11] Future studies to understand the molecular differences within this heterogeneous group of cVS are needed.

This study has several limitations. Despite many cystic tumors and being a multi-institutional study, this is still a retrospective cohort. We recognize that cVSs were significantly larger, which could be a confounding factor. We therefore sought to address this using multivariate analyses as well as subanalysis of size-matched tumors. It is also possible that microscopic characteristics of cVS can be contributing to the variation we see in our cVS cohort, and future studies that would better characterize molecular architecture in these cystic tumors would provide important insights. We also recognize that differences in operative approaches and surgeon familiarity with cVS can significantly impact postoperative outcomes. In both institutions, we generally utilize the translabyrinthine approach for tumors that are greater than 2.5 cm in patients with nonserviceable hearing, or in patients where hearing preservation is considered unlikely. We hope that by presenting the first multi-institutional cohort of cVS patients, we can provide some consistency and large-scale cohort data to motivate future avenues for research.

CONCLUSION

cVSs have been described to have worse FN outcomes and higher rates of STR compared with sVS. Here, we present the first, and to our knowledge, the largest multi-institutional cohort study of cVS patients. We illustrate that macrocytic components and tumor size could be potentially interrelated in their predictive value of poor FN outcomes, and that surgical approach could be independently associated with FN outcomes. In our size- and surgical approach-matched subanalysis, we no longer see these differences, further supporting this hypothesis. We also demonstrate that there are significantly lower rates of GTR in cVS compared with sVS, likely secondary to the presence of peritumoral/pericystic adhesions, making complete tumor resection difficult to achieve. Further investigation is required to identify predictors of clinical outcomes in patients with cVS undergoing microsurgical resection.

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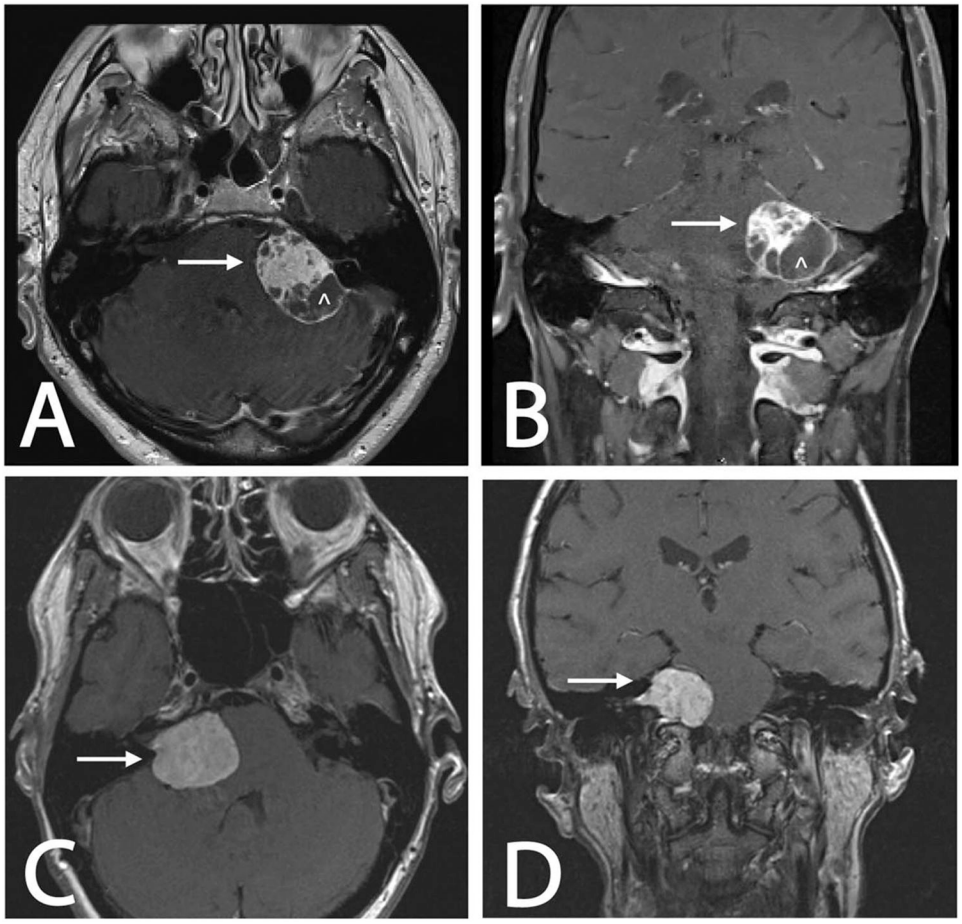

FIG. 1.

Representative MRI images of cVS and sVS. *A* and *B*, MRI from a patient with a cVS. *C* and *D*, MRI from a patient with an sVS matched in tumor size. Axial T1-weighted contrast-enhanced (*A*, *C*) and coronal T1-weighted contrast-enhanced images (*B*, *D*) are shown. Tumor is marked with *arrows*, and the macrocystic components are marked with *arrowheads*. cVS indicates cystic vestibular schwannoma; MRI, magnetic resonance imaging; sVS, solid vestibular schwannoma; VS, vestibular schwannoma.

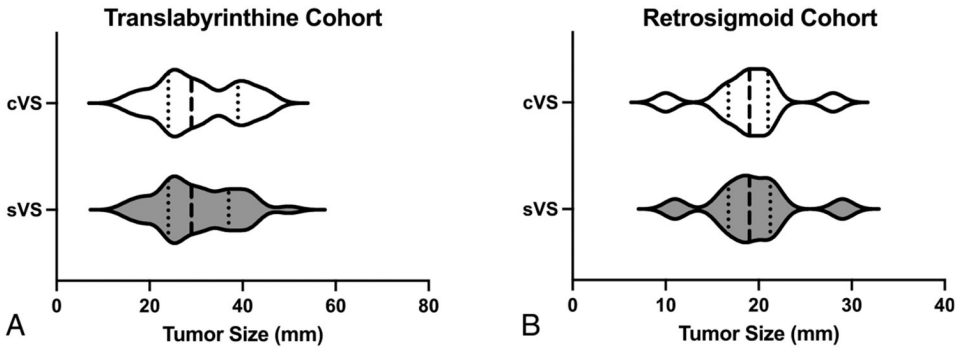

FIG. 2.

Size- and surgical approach-matched cystic and sVS cohorts. *A*, Box violin plot demonstrating the distribution of tumor size measured at the time of translabyrinthine surgery in cVS and sVS groups after size matching (N = 35 matched pairs). *B*, Box violin plot demonstrating the distribution of tumor size in the retrosigmoid cVS and sVS groups (N = 10 matched pairs). The *dotted lines* indicate 25%, median, and 75% percentiles, respectively. cVS indicates cystic vestibular schwannoma; sVS, solid vestibular schwannoma.

TABLE 1.

Clinical characteristics of patients with cVS and sVS

	cVS (N = 46)	sVS (N = 269)	*P*
Demographics			
Age (yrs)	55 (SD, 13.4)	50 (SD, 12.7)	0.07
Sex			**0.03** **
Male	23 (50%)	91 (34%)	
Female	23 (50%)	178 (66%)	
Side			1.0
Left	24 (52%)	140 (52%)	
Right	22 (48%)	129 (48%)	
Tumor maximum diameter (cm)	2.8 (SD, 0.96)	1.8 (SD, 0.95)	**<0.001** **
Preoperative symptoms			
Dizziness	27 (59%)	157 (59%)	1.0
Tinnitus	33 (72%)	203 (75%)	0.6
Dysphonia	1 (2%)	0 (0%)	**0.02** **
Dysphagia	2 (4%)	1 (0 3%)	**0.01** **

All percentages are calculated within subgroup analyses (within cVS and sVS cohorts, respectively). There were no patients who presented with facial weakness, and thus, this was not included in the table below. Statistically significant predictors were calculated with $p < 0.05$ (bolded, labeled with **). SD was calculated where appropriate.

TABLE 2.

Intraoperative and postoperative characteristics of patients with cVS versus sVS

	cVS (N = 46)	sVS (N = 269)	*p*
Surgical approach			
Translabyrinthine	35 (76%)	135 (50%)	**0.001** **
Retrosigmoid	10 (22%)	68 (25%)	
Middle cranial fossa	1 (2%)	66 (25%)	
Extent of resection			
GTR or near-total resection	32 (70%)	234 (87%)	**0.003** **
STR	14 (30%)	35 (13%)	
Mean duration of follow-up (mo)	16.2 (9.7)	17.6 (10.1)	0.4
Immediate postoperative period			
Good FN function (HB I/II)	36 (78%)	232 (86%)	0.16
Dizziness	34 (74%)	209 (78%)	0.6
Tinnitus	23 (50%)	124 (46%)	0.9
Lower cranial nerve symptoms			
Voice changes	1 (2%)	2 (0.7%)	0.3
Dysphagia	9 (20%)	21 (8%)	**0.01** **
Shoulder weakness	0 (0%)	0 (0%)	1.0
Long-term postoperative period			
Good FN function	37 (80%)	240 (90%)	**0.048** **
Dizziness[a]	22 (49%)	108 (40%)	0.3
Tinnitus[b]	17 (41%)	103 (39%)	0.8
Lower cranial nerve symptoms			
Voice changes	1 (2%)	1 (0.3%)	0.2
Dysphagia	4 (9%)	2 (0.6%)	**<0.001** **
Shoulder weakness	1 (2%)	0 (0%)	**0.02** **

[a] A total of 45 cVSs with complete follow-up data were included.

[b] A total of 236 sVSs and 41 cVSs with complete follow-up data were included.

Immediate postoperative characteristics and long-term postoperative characteristics (≥6 mo) were collected. All percentages are calculated within subgroup analyses (within cVS vs. sVS cohorts, respectively). Statistically significant predictors were calculated with $p < 0.05$ (bolded, labeled with **). SD was calculated where appropriate.

TABLE 3.

Additional predictors of postoperative FN outcomes

	Long-Term Postoperative Period (>1 yr)			Multivariable Model	
	Good Postoperative FN Function (N = 280)	**Poor Postoperative FN Function (N = 35)**	***p***	**Adjusted OR (CI)**	**Adjusted *p***
Demographics					
Age (yrs)	50 (SD, 12.9)	52 (SD, 13.4)	0.5		
Sex			0.6		
Male	100 (36%)	14 (40%)			
Female	180 (64%)	21 (60%)			
Side					
Left	150 (54%)	14 (40%)	0.1		
Right	130 (46%)	21 (60%)			
Tumor characteristics					
Tumor maximum diameter (cm)	1.8 (SD, 9.8)	2.6 (SD, 10.3)	**0.009** **	0.96 (0.92–1.0)	0.06
Cystic	37 (13%)	9 (25%)	**0.048** **	0.8 (0.3–2.0)	0.64
Surgical approach					
Translabyrinthine	140 (50%)	30 (86%)	**<0.001** **	–	
Retrosigmoid	75 (27%)	3 (9%)		**4.2 (1.2–14.7)**	**0.02** **
Middle cranial fossa	65 (23%)	2 (6%)		3.6 (0.73–18.0)	0.11
Extent of resection					
GTR or near-total resection	240 (86%)	26 (74%)	0.08		
STR	40 (14%)	9 (26%)			

Immediate postoperative characteristics and long-term postoperative characteristics (≥6 mo) were collected. All percentages are calculated within subgroup analyses (within good vs. poor FN outcomes, respectively). Poor FN function was defined as an HB score of III or higher. Statistically significant predictors were calculated with $p < 0.05$ (bolded, labeled with **). Statistically significant predictors on univariate analysis (tumor size, surgical approach, and presence of cystic component) were included in a multivariate analysis, with adjusted OR and CI included. SD was calculated where appropriate.

TABLE 4.

Intraoperative and postoperative characteristics of size-matched cVS versus sVS after translabyrinthine and retrosigmoid microsurgical resection

	Translabyrinthine Microsurgical Resection			Retrosigmoid Microsurgical Resection		
	cVS (n = 35)	**sVS (n = 35)**	***P***	**cVS (n = 10)**	**sVS (n = 10)**	***P***
Demographics and follow-up period						
Age (yrs)	54.1 (SD, 14.8)	46.6 (SD, 16.4)	0.304	59.2 (SD, 4.1)	49.8 (SD, 11.6)	0.125
Mean postoperative follow-up time (mo)	17.1 (SD, 7.5)	18.7 (SD, 9.1)	0.468	16.7 (SD, 15.2)	17.5 (SD, 6.0)	0.879
Sex						
Male	18 (51%)	12 (34%)	0.227	5 (50%)	4 (40%)	0.653
Female	17 (49%)	23 (66%)	0.227	5 (50%)	6 (60%)	0.653
Tumor characteristics						
Right-sided tumors	17 (49%)	14 (40%)	0.631	5 (50%)	9 (90%)	0.051
Mean maximum tumor diameter at time of surgery (mm)	30.6 (SD, 8.8)	30.2 (SD, 8.5)	0.858	19.1 (SD, 4.6)	19.3 (SD, 4.6)	0.900
Extent of resection						
GTR or near-total resection	22 (63%)	21 (60%)	0.806	9 (90%)	10 (100%)	0.305
STR	13 (37%)	14 (40%)	0.806	1 (10%)	0 (0%)	0.305
Immediate postoperative characteristics						
Good FN function (HB grade I-II)	26 (74%)	27 (77%)	0.784	10 (100%)	10 (100%)	N/A
Dizziness	28 (80%)	21 (60%)	0.068	7 (70%)	9 (90%)	0.264
Tinnitus	15 (83%)[a]	11 (33%)[a]	**<0.001****	7 (70%)[b]	4 (57%)[b]	0.585
Lower cranial nerve symptoms						
Voice changes	0 (0%)	0 (0%)	N/A	0 (0%)	0 (0%)	N/A
Dysphagia	0 (0%)	2 (6%)	0.156	0 (0%)	0 (0%)	N/A
Shoulder weakness	0 (0%)	0 (0%)	N/A	0 (0%)	0 (0%)	N/A
Long-term postoperative characteristics						
Good FN function (HB grade I-II)	27 (77%)	25 (71%)	0.785	10 (100%)	10 (100%)	N/A
Dizziness	9 (26%)	15 (43%)	0.160	4 (40%)	3 (30%)	0.639
Tinnitus[c]	13 (81%)[c]	9 (21%)[c]	**<0.001****	4 (40%)[d]	3 (50%)[d]	0.696
Lower cranial nerve symptoms						
Voice changes	0 (0%)	0 (0%)	N/A	0 (0%)	0 (0%)	N/A
Dysphagia	0 (0%)	0 (0%)	N/A	0 (0%)	0 (0%)	N/A

	Translabyrinthine Microsurgical Resection			Retrosigmoid Microsurgical Resection		
	cVS (n = 35)	**sVS (n = 35)**	***P***	**cVS (n = 10)**	**sVS (n = 10)**	***P***
Shoulder weakness	0 (0%)	0 (0%)	N/A	0 (0%)	0 (0%)	N/A

[a] A total of 18 cVSs and 33 sVSs with complete follow-up were included here.

[b] A total of 10 cVSs and 7 sVSs with complete follow-up were included here.

[c] A total of 16 cVSs and 31 sVSs with complete follow-up were included here.

[d] A total of 10 cVSs and 6 sVSs with complete follow-up were included here.

cVS were matched with sVS by maximal diameter at time of surgery (88% within 2 mm, 100% within 4 mm). Immediate postoperative characteristics (<3 d) and long-term postoperative characteristics (≥6 mo) were collected. Size-matched cVS and sVS were selected for translabyrinthine and retrosigmoid surgical approach and analyzed. All percentages were calculated within subgroup analysis (within cVS vs. sVS cohorts with complete data points, respectively). Statistical significance was defined as $p < 0.05$ (bolded, labeled with **), and SDs are listed where applicable. *p* values are listed for chi-square test (nominal variables) and unpaired Student's *t* test (numerical variables).