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Presence of a fundal fluid cap on preoperative magnetic resonance imaging may predict long-term facial nerve function after resection of vestibular schwannoma via the retrosigmoid approach

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OBJECTIVE Preservation of neurological function is a priority when performing a resection of a vestibular schwannoma (VS). Few studies have examined the radiographic value of a fundal fluid cap—i.e., cerebrospinal fluid in the lateral end of a VS within the internal auditory canal—for prediction of postoperative neurological function. The aim of this study was to clarify whether the presence of a fundal fluid cap on preoperative magnetic resonance images has a clinical impact on facial nerve function after resection of VSs.

METHODS The presence of a fundal fluid cap and its prognostic impact on long-term postoperative facial nerve function were analyzed.

RESULTS A fundal fluid cap was present in 102 of 143 patients who underwent resection of sporadic VSs via the retrosigmoid approach. Facial nerve function was acceptable (House-Brackmann grade I–II) immediately after surgery in 82 (80.4%) patients with a fundal fluid cap and in 26 (63.4%) of those without this sign. The preservation rate of facial nerve function increased in a time-dependent manner after surgery in patients with a fundal fluid cap but plateaued by 3 months postoperatively in those without a fundal fluid cap; the difference was statistically significant at 12 months (96.1% vs 82.9%, p = 0.013) and 24 months (97.1% vs 82.9%, p = 0.006) after surgery. The presence of a fundal fluid cap had a significantly positive effect on long-term facial nerve function at 24 months after surgery when tumor size and intraoperative neuromonitoring response were taken into account (OR 5.55, 95% CI 1.12–27.5, p = 0.034).

CONCLUSIONS Neuromonitoring-guided microsurgery for total resection of VSs is more likely to be successful in terms of preservation of facial nerve function if a fundal fluid cap is present. This preoperative radiographic sign could be helpful when counseling patients and deciding the treatment strategy.

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KEYWORDS vestibular schwannoma; retrosigmoid approach; facial nerve function; fundal fluid cap

A VESTIBULAR schwannoma (VS) is a benign tumor in the cerebellopontine angle that originates from the Schwann cells of the Obersteiner-Redlich zone in the vestibular division of the vestibulocochlear nerve.[1] The goal of treatment for VSs is to achieve a balance between tumor control and preservation of neurological function, while trying to avoid the problems that would occur if the natural course was left untreated. The management options for VSs include observational wait-and-scan, microsurgery, and/or stereotactic radiosurgery.[1,2] Although each treatment has its advantages and disadvantages, resection has the benefit of being curative.[1–6] The outcomes of surgery for VSs have improved remarkably with the evolution of microsurgical techniques and intraoperative neuromonitoring, with little morbidity and almost no mortality.[7–11] However, even now, neurological deterioration, especially facial nerve paralysis, cannot be completely avoided when the VS is treated surgically.[11] Postoperative facial nerve

ABBREVIATIONS FFC = fundal fluid cap; IAC = internal auditory canal; MR = magnetic resonance; VS = vestibular schwannoma.

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dysfunction is associated with depression and intractable persistent postoperative headache, which has a devastating impact on quality of life in patients with VSs.[12–15]

Preoperative prediction of postoperative neurological deterioration would enable more appropriate counseling and decision-making regarding the treatment strategy for patients with a VS. Several studies have reported that the presence of cerebrospinal fluid in the most lateral end of a tumor in the internal auditory canal (IAC) on preoperative magnetic resonance (MR) images predicts preservation of hearing after treatment for VSs.[16–19] This radiographic feature is known as a fundal fluid cap. The preoperative presence of a fundal fluid cap reportedly increases the likelihood of hearing preservation after microsurgical resection or stereotactic radiosurgery. However, the clinical value of a fundal fluid cap as a predictor of postoperative facial nerve function has not been fully investigated.

In theory, the presence of a fundal fluid cap indicates that less bone drilling is needed and dissection in the IAC will be easier. Accordingly, we hypothesized that facial nerve function after VS resection would be better in patients in whom a fundal fluid cap was detected on preoperative MR images. The aim of this study was to clarify the relationship between the presence of a fundal fluid cap on preoperative MR images and postoperative facial nerve function in patients who underwent microsurgical resection of VSs.

Methods

Study Design

In total, 174 consecutive patients with VSs were treated surgically via a retrosigmoid approach by the same senior skull base neurosurgeon (E.K.) at our institution between January 2011 and March 2020. The following inclusion criteria were applied: a newly diagnosed sporadic VS that had not been treated with neoadjuvant stereotactic radiosurgery; postoperative follow-up duration ≥ 2 years; and age ≥ 20 years. Thirty-one patients were excluded because they had neurofibromatosis type 2 (n = 12) or recurrence (n = 7), underwent stereotactic radiosurgery before surgery (n = 5), were lost to follow-up within 2 years after surgery (n = 4; House-Brackmann grade I–II at the last follow-up), or were aged < 20 years (n = 3). This left 143 patients for analysis. The patients were allocated to the fundal fluid cap (FFC) group if a fundal fluid cap was detected on preoperative MR images and to the non-FFC group if not. Figure 1 shows the patient selection process.

First, we compared the following baseline characteristics between groups: age, sex, tumor laterality, tumor size (maximum cerebellopontine angle[20] and Koos grade[21]), findings on preoperative MR images (including presence of fluid cystic change and a high jugular bulb), intraoperative findings (including tumor hardness [hard/moderate/soft], tumor vascularity [rich/moderate/poor], adhesion between the tumor and facial nerve [severe/moderate/mild], response of the facial nerve on monitoring [good/decreased/disappearance], and nerve of origin of the tumor), extent of resection (total, i.e., complete removal; near-total, only a small remnant on the facial nerve under the microscope; and subtotal, remnant detectable on MR imaging), operation time, postoperative hearing status, postoperative hydrocephalus requiring a ventriculoperitoneal shunt, and postoperative adjuvant stereotactic radiosurgery. Intraoperative findings were extracted from the operative records, subjectively graded by two independent investigators (Y.F. and Y.U.), and then checked by a third investigator (E.K.). Second, we retrospectively assessed postoperative time-dependent changes in facial nerve function (House-Brackmann grade[22]) recorded at 1–3 days and 3, 6, 12, and 24 months after surgery in each group. Finally, we assessed the clinical significance of a fundal fluid cap on preoperative MR imaging as a predictor of facial nerve function at 24 months after surgery. For this study, favorable facial nerve function was defined as House-Brackmann grade I–II.

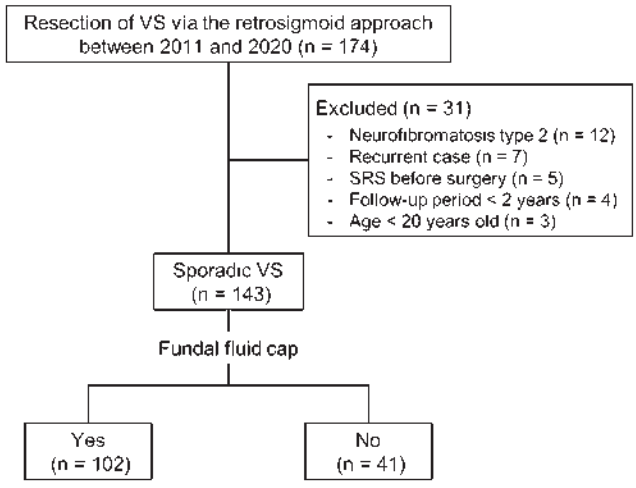

FIG. 1. Flowchart showing the patient selection process. SRS = stereotactic radiosurgery.

The study was approved by our institutional review board and was conducted according to institutional and national ethical guidelines and the Declaration of Helsinki. The need for informed consent was waived in view of the retrospective observational nature of the research.

MR Imaging Analysis

Conventional examinations for a cerebellopontine tumor were performed using a 3-T MR scanner (Achieva, Philips Medical Systems) and included T2-weighted images with 3-dimensional driven equilibrium (fast-spin-echo sequence; TR/TE 1500/174 msec; field of view 150 × 150 mm; matrix 320 × 256; slice thickness 1.4 mm; flip angle 90°; bandwidth 439 Hz/pixel) and T2-weighted balanced fast field-echo images (gradient-echo sequence; TR/TE 5.2/2.1 msec; field of view 150 × 150 mm; matrix 256 × 256; slice thickness 1.4 mm; flip angle 45°; bandwidth 561 Hz/pixel) before and after injection of intravenous gadolinium contrast agent (0.2 ml/kg Magnescope [Guerbet]).

A fundal fluid cap was defined as in previous studies (Fig. 2)[19,23] and identified on axial T2-weighted images with driven equilibrium. The maximum length was measured from the lateral end of the tumor to the fundus of the IAC (Supplemental Fig. 1). Images were assessed for the presence of a fundal fluid cap by two investigators (E.K.

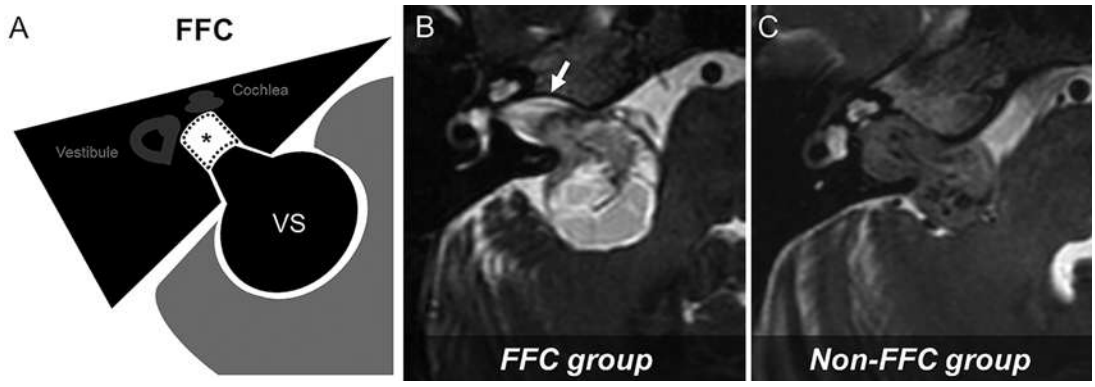

FIG. 2. Schematic illustration of a cerebellopontine angle demonstrating a fundal fluid cap (*dotted line with asterisk*) (**A**). Preoperative T2-weighted MR images with driven equilibrium showing representative cases included in the FFC group (**B**) and non-FFC group (**C**). The *arrow* in panel B indicates the fundal fluid cap.

and Y.F.) working independently and checked by a third investigator (Y.U.). The size of the fundal fluid cap was measured by the same neurosurgeon (Y.F.) and confirmed by a second neurosurgeon (Y.U.).

Surgical Strategy and Retrosigmoid Approach for VS Resection

Our surgical policy for VS resection was to remove the maximum amount of tumor tissue possible with preservation of facial nerve function. We avoided limiting the extent of resection to preserve hearing, with the exception of patients with a small VS whose hearing was almost normal preoperatively. However, preservation of facial nerve function was prioritized over total resection if the facial nerve could not be adequately recognized because of heavy bleeding from the tumor, if a safe peeling plane on the facial nerve could not be secured due to strong adhesion with the tumor, and if there was a reduced response on facial nerve monitoring of the root exit zone.

We performed resections of VSs by using a retrosigmoid approach in a consistent manner.[13] The patient was placed in the park-bench position. A linear postauricular incision (total length 10 cm) and suboccipital craniectomy (4 × 4 cm) were performed without decompression of the foramen magnum. After incision of the dura mater along the transverse sinus and sigmoid sinus, the tumor was removed microsurgically while monitoring the facial nerve (NIM-Neuro 3.0, Medtronic Xomed) with or without recording of auditory brainstem responses. The IAC was drilled when necessary to remove the tumor. Finally, primary watertight closure of the dura, cosmetic cranioplasty with bone dust collected at the time of the craniectomy, and suturing of muscles and skin were performed.

Statistical Analysis

Baseline characteristics were compared between the two groups by using the Mann-Whitney U-test and Fisher's exact test. Spearman's rank correlation coefficient was used to assess the linearity of the relationship between size of the fundal fluid cap and size of the tumor. Fisher's exact test was used to compare facial nerve function between groups at each assessment time.

Univariate logistic regression analysis was performed to determine whether any of the preoperative and intraoperative features, including presence of a fundal fluid cap, were significantly associated with long-term facial nerve function after VS resection. Multivariate logistic regression analyses were performed with adjustment based on the results of the univariate analysis (including variables with $p < 0.05$). ORs were calculated with their corresponding 95% CIs. Interobserver agreement regarding the presence of a fundal fluid cap was assessed by using Cohen's kappa statistic ($\kappa \leq 0.4$, poor agreement; $0.4 < \kappa \leq 0.6$, moderate agreement; $0.6 < \kappa \leq 0.8$, good agreement; $0.8 < \kappa$, substantial agreement).

All statistical analyses were performed by using EZR (Saitama Medical Center, Jichi Medical University), which is a graphical user interface for R (R Foundation for Statistical Computing).[24] Two-sided $p < 0.05$ was considered statistically significant.

Results

Patient Characteristics

In total, 143 patients were analyzed in this study. There were 102 (71.3%) patients (42 men and 60 women; median [interquartile range] age 48 [40–58] years) in the FFC group and 41 (28.7%) patients (16 men and 25 women; median [interquartile range] age 44 [32–58] years) in the non-FFC group. The median (interquartile range) preoperative tumor size (maximum cerebellopontine angle) was 25 (17–32) mm in the FFC group and 30 (18–38) mm in the non-FFC group. There were 85 (83.3%) tumors in contact with the brainstem (Koos grade ≥ 3) in the FFC group and 34 (82.9%) in the non-FFC group. The baseline patient characteristics and operative details are summarized according to fundal fluid cap status in Table 1. There were no statistically significant between-group differences for any characteristic, except for a shorter operation time in the FFC group ($p = 0.045$).

Fundal Fluid Cap

The interobserver consensus regarding the presence of a fundal fluid cap indicated substantial agreement ($\kappa = 1.0$). The size of the fundal fluid cap was not significantly

TABLE 1. Patient demographic and tumor characteristics according to fundal fluid cap status

Characteristic	FFC Group (n = 102)	Non-FFC Group (n = 41)	p Value
Age, yrs	48 (40–58)	44 (32–58)	0.126
Sex			
Male	42 (41.2)	16 (39.0)	0.853
Female	60 (58.8)	25 (61.0)	
Tumor laterality			
Rt	38 (37.3)	23 (56.1)	0.061
Lt	64 (62.7)	18 (43.9)	
Preop tumor size			
Max CPA, mm	25 (17–32)	30 (18–38)	0.123
Large (>30 mm)	32 (31.4)	20 (48.8)	0.057
Koos classification			
Grade 1	0 (0)	2 (4.9)	0.200
Grade 2	17 (16.7)	5 (12.2)	
Grade 3	23 (22.5)	8 (19.5)	
Grade 4	62 (60.8)	26 (63.4)	
Preop MR imaging findings			
Cystic change	23 (22.5)	11 (26.8)	0.665
High jugular bulb	8 (7.8)	5 (12.2)	0.520
Intraop findings*			
Tumor hardness			0.887
Hard	60 (58.8)	25 (62.5)	
Moderate	31 (30.4)	12 (30.0)	
Soft	11 (10.8)	3 (7.5)	
Tumor vascularity			0.576
Rich	56 (54.9)	22 (55.0)	
Moderate	38 (37.3)	17 (42.5)	
Poor	8 (7.8)	1 (2.5)	
Adhesion btwn tumor & facial nerve			0.173
Severe	59 (57.8)	19 (47.5)	
Moderate	32 (31.4)	19 (47.5)	
Mild	11 (10.8)	2 (5.0)	
Facial nerve monitoring			0.251
Good response	94 (92.2)	34 (85.0)	
Poor response	2 (2.0)†	0 (0)	
Decreased response	5 (4.9)	5 (12.5)	
Disappearance of response	1 (1.0)	1 (2.5)	
Origin of VS			0.968
Superior vestibular nerve	40 (39.2)	15 (36.6)	
Inferior vestibular nerve	48 (47.1)	20 (48.8)	
Unidentified	14 (13.7)	6 (14.6)	
Extent of resection			
Total	67 (65.7)	24 (58.5)	0.282
Near-total	27 (26.5)	10 (24.4)	
Subtotal	8 (7.8)	7 (17.1)	
Op time, hrs	4.7 (4.0–5.8)	5.3 (4.4–7.1)	0.045
Postop hearing loss	77 (75.5)	33 (80.5)	0.662
Postop hydrocephalus requiring VPS	0 (0)	0 (0)	>0.999
Postop adjuvant SRS	1 (1.0)	1 (2.4)	0.493

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TABLE 1. Patient demographic and tumor characteristics according to fundal fluid cap status

CPA = cerebellopontine angle; SRS = stereotactic radiosurgery; VPS = ventriculoperitoneal shunt surgery.
Values are reported as median (interquartile range) or number (%).
* One patient in the non-FFC group lacked intraoperative data.
† Response was poor even before tumor resection due to the effects of unintended muscle relaxant administration.

correlated with tumor size (r = –0.028, p = 0.739) (Fig. 3A). The median (interquartile range) fundal fluid cap size was 4.9 (3.2–6.1) mm in the FFC group. Representative cases with or without a fundal fluid cap are shown according to whether the VS was small or large (Fig. 3B).

Postoperative Facial Nerve Function

No patients in either study group had preoperative moderate or severe facial nerve paralysis (House-Brackmann grade ≥ III). Figure 4 shows the outcomes in terms of facial nerve function. Overall, the facial nerve was morphologically preserved in 142 (99.3%) patients, with the exception of 1 patient in the FFC group. Eighty-two (80.4%) patients in the FFC group had favorable facial nerve function immediately after surgery. After surgery, the functional preservation rate increased in a time-dependent manner and continued to increase for as long as 24 months (90.2% at 3 months, 93.1% at 6 months, 96.1% at 12 months, and 97.1% at 24 months). In contrast, only 26 (63.4%) patients in the non-FFC group had favorable facial nerve function immediately after surgery. The functional preservation rate increased to 82.9% during the first 3 months but plateaued thereafter, remaining at 82.9% at 6, 12, and 24 months. No patient in either group showed deterioration in House-Brackmann grade after 3 months postoperatively.

The rate of preservation of favorable facial nerve function was consistently higher in the FFC group than in the non-FFC group; the difference was significant at 12 months (96.1% vs 82.9%, p = 0.013) and 24 months (97.1% vs 82.9%, p = 0.006) after surgery.

Predictive Factors Contributing to Long-Term Facial Nerve Function

Preoperative characteristics (age, sex, presence of a fundal fluid cap, cystic change, and tumor size) and intraoperative features (hardness, vascularity, adhesion, and facial nerve monitoring response) were examined in univariate analyses. The presence of a fundal fluid cap (OR 6.79, p = 0.008), tumor size ≤ 30 mm (OR 4.56, p = 0.034), and good response on intraoperative facial nerve monitoring (OR 17.2, p < 0.001) were significant predictors of favorable facial nerve outcome at 24 months after surgery (Table 2). No other feature was associated with facial nerve function at 24 months after surgery (Supplemental Table 1).

In multivariate analysis with adjustment, the presence of a fundal fluid cap remained a significant independent predictor of favorable facial nerve function at 24 months after VS resection (OR 5.55, p = 0.034) (Table 2). Furthermore, even when adjusted for only tumor size, the presence of a fundal fluid cap remained a significant independent predictor of favorable facial nerve function at 24 months after VS resection (OR 5.70, p = 0.017) (Supplemental Table 2).

Discussion

Preservation of neurological function, especially that of

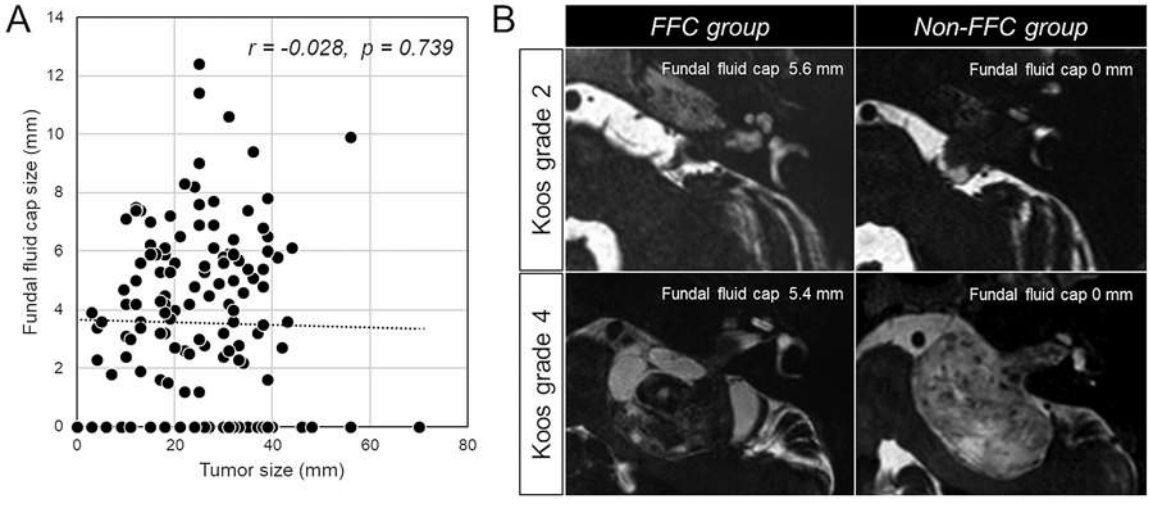

FIG. 3. Scatterplot showing the correlation between fundal fluid cap size and tumor size (maximum cerebellopontine angle) (**A**). Spearman's rank correlation coefficient (r) and significance (p) values are presented. Preoperative T2-weighted MR images with driven equilibrium showing representative cases of Koos grade 2 and grade 4 VSs included in the FFC and non-FFC groups (**B**).

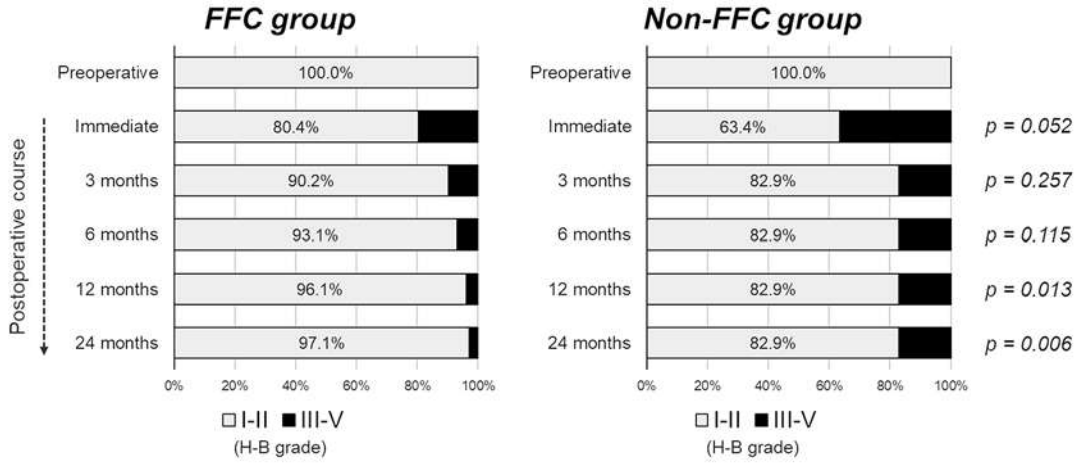

FIG. 4. Distribution of preoperative and postoperative House-Brackmann (H-B) grades in the FFC and non-FFC groups, showing the facial nerve function outcomes in each group. All patients (n = 143), including 102 in the FFC group and 41 in the non-FFC group, were evaluated at each interval. The proportions of patients with good facial nerve function (H-B grade I–II) at each time point are shown. The p values for each time point are listed (*far right*).

the facial nerve, is a priority in resection of VSs.[1,9,10] The ability to predict how difficult it would be to preserve facial nerve function in advance of surgery would be useful when counseling patients and selecting appropriate candidates for surgery. In this study, we investigated the clinical impact of the presence of a fundal fluid cap on preoperative MR images on postoperative facial nerve function in a case series in which all operations were performed by the same neurosurgeon using consistent procedures and intraoperative judgment. The presence of a fundal fluid cap was a significant prognostic radiographic predictor of long-term facial nerve function after VS resection via the retrosigmoid approach.

Fundal Fluid Cap on Preoperative MR Imaging

We identified a fundal fluid cap on preoperative MR images in 71.3% of our patients, and we did not identify any differences in patient or tumor characteristics according to whether this radiographic sign was present. This relatively high rate probably reflects differences in the MR sequences used for radiographic assessment. We judged the presence of a fundal fluid cap on heavily T2-weighted images obtained with a fast-spin-echo sequence. This sequence suppresses magnetic susceptibility artifacts and enables evaluation of the IAC up to the fundus in detail, despite the long acquisition time due to the low signal-to-noise ratio.[25] On the other hand, the gradient-echo sequence—one of the heavily T2-weighted images utilized in most previous studies[18,19,23,26–29]—provides a gadolinium contrast effect that is suitable for assessing the cranial nerves in the cistern.[26] However, the gradient-echo sequence has the disadvantage of magnetic susceptibility artifacts, which result in inadequate assessment in the IAC.[27] Therefore, the prevalence rates for a fundal fluid cap in the previous studies that utilized only the gradient-echo sequence were lower (40%–59%) than in our present study.[18,19,23,28,29] Furthermore, we could not find an association between size of the fundal fluid cap and size of the tumor, which is in contrast with the significant association reported by Sullivan et al.[23] These conflicting findings suggest that evaluation of extension of the VS into the IAC is influenced by the MR sequences used.

Facial Nerve Function and Predictive Factors

Tumor size is generally considered a predictor of facial nerve function after resection of a VS.[11,30–32] Intraoperative neuromonitoring also has a strong association with facial nerve function after this surgery.[10,33] Improvement in facial

TABLE 2. Univariate and multivariate analyses of potential predictors of favorable facial nerve function at 24 months after surgery

Factor	Univariate		Multivariate	
	OR (95% CI)	p Value	OR (95% CI)	p Value
Fundal fluid cap (w/ vs w/o)	6.79 (1.66–27.8)	0.008	5.55 (1.12–27.5)	0.034
Tumor size (maximum CPA) (≤30 mm vs >30 mm)	4.56 (1.13–18.5)	0.034	2.61 (0.53–13.0)	0.241
Intraop facial nerve monitoring response (good vs poor/decrease/disappearance)	17.2 (3.93–75.6)	<0.001	14.2 (2.93–69.2)	<0.001

nerve function during postoperative follow-up has been documented in patients in whom anatomical structures were successfully preserved and response to neuromonitoring was good.[10,11,34] We performed VS resection guided by intraoperative facial nerve monitoring and achieved total and near-total resection in 89.5% of patients. Overall, facial nerve function (House-Brackmann grade I–II) was favorable in 75.5% of our patients immediately after surgery and in 93.0% at 24 months postoperatively. This rate is satisfactory when compared with the rates of previous reports.[11,34,35]

Interestingly, we found that the fundal fluid cap had a significantly positive prognostic impact on long-term facial nerve function after resection of a VS when tumor size and response to intraoperative neuromonitoring were taken into account. The presence of a fundal fluid cap confers an advantage during microsurgery because drilling of the entire IAC is unnecessary. The distance between the tumor and fundus makes it easier to gain control of the most lateral part of the tumor in the IAC and follow the facial nerve dissection at the inferior aspect of the tumor. These technical considerations are reflected in the significant difference in operation time between the two groups in our study. Rompaey et al. put forward a hypothesis similar to ours and tried to clarify the significance of the presence of fluid in the lateral portion of VS in the IAC in terms of postoperative facial nerve function.[29] In their study, the absence of a fundal fluid cap had a significantly negative prognostic impact on short-term facial nerve function after resection of VSs. We noted the same trend in our study, and we also found a difference in the course of facial nerve function after surgery in that patients with a fundal fluid cap showed improvement 2 years after surgery, with the exception of 1 case in which nerve laceration occurred intraoperatively. In contrast, there was no further postoperative improvement in facial nerve function after 3 months in patients without the fundal fluid cap, resulting in a significant difference in long-term facial nerve function after resection of the VS.

Although we successfully demonstrated that the fundal fluid cap is an independent radiographic predictor of postoperative facial nerve function in patients with VSs, the exact mechanisms underpinning this finding remain unclear. A difference in the site of origin of VS may help explain why the fundal fluid cap has a favorable effect. It is widely believed that a VS arises from the glial-Schwann sheath junction, also known as the Obersteiner-Redlich zone, and is typically located at or medial to the porus of the IAC.[36] Roosli et al. demonstrated that a histopathological VS could arise anywhere from the glial-Schwann sheath junction to the nerve terminals within the vestibular sense organs.[37] Differences in tumor biology may lead to differences in the direction of tumor growth, the extent to which the tumor fills the IAC, and the extent of adhesion to the facial nerve. VSs without a fundal fluid cap would originate more lateral to the glial-Schwann sheath junction and more adjacent to the fundus. These features could potentially cause more stretching and mechanical injury to the facial nerve during microsurgery as a result of unintentional blind dissection at the fundus. Intricate damage of this type may lead to differences in not only facial nerve function immediately after surgery but also the subsequent recovery. Further investigations are necessary to improve the surgical outcome.

Limitations

Our study had several limitations. First, it was conducted at a single institution and the number of patients who underwent surgery was small. Moreover, the study had a retrospective design. Therefore, we cannot exclude the possibility of bias in the study population, and we were unable to fully examine indeterminate potential factors affecting postoperative facial nerve function. However, our report is based on the largest number of investigated patients with a fundal fluid cap to date. Second, the intraoperative findings were subjectively graded. Therefore, it would be desirable to use a globally accepted grading scale to assess intraoperative findings in a future study. Third, we used only the retrosigmoid approach for VS resection. This approach is familiar to neurosurgeons, suitable for the removal of VSs of all sizes, and generally superior to other approaches in terms of preserving facial nerve function.[1,38] However, the applicability of our findings to patients treated with other surgical approaches requires further investigation. Finally, the effect of differences in surgical strategy between centers cannot be excluded. Our strategy has always been to attempt total resection for VSs while preserving facial nerve function. However, other authors have proposed subtotal resection followed by stereotactic radiosurgery with the aim of optimal preservation of function.[39] The prognostic significance of the fundal fluid cap in patients treated with this alternative strategy requires further investigation.

Conclusions

This study has provided evidence that a fundal fluid cap on preoperative MR imaging predicts long-term facial nerve function after microsurgical resection of a VS via the retrosigmoid approach. There was greater likelihood of favorable facial nerve function when a fundal fluid cap was present preoperatively in patients who underwent total resection with neuromonitoring-guided microsurgery for VSs. This preoperative radiographic sign could help when counseling patients and deciding the treatment strategy.

Acknowledgments

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Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: Fujita. Acquisition of data: Fujita, Uozumi. Analysis and interpretation of data: Fujita, Uozumi. Drafting the article: Fujita. Critically revising the article: all authors. Reviewed submitted version of manuscript: Uozumi, Sasayama, Kohmura. Approved the final version of the manuscript on behalf of all authors: Fujita. Statistical analysis: Fujita, Uozumi. Administrative/technical/material support: Fujita. Study supervision: Sasayama, Kohmura.

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