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Initial Cisternal Access for Cerebrospinal Fluid Release During Retrosigmoid Resection of Large Vestibular Schwannomas: A Surgeon-Stratified Comparative Cohort Study

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Abstract

Adequate cerebrospinal fluid (CSF) release facilitates cerebellar relaxation during retrosigmoid resection of large vestibular schwannomas (VSs). We compared initial CSF-release access via the cisterna magna (CM) versus lateral cerebellomedullary cistern (LCMC). This retrospective cohort included 100 patients with large VSs (maximum extrameatal tumor diameter ≥ 30 mm) undergoing primary retrosigmoid microsurgery. Six surgeons used both routes without standardized preoperative selection. CM access was used in 53 patients and LCMC access in 47. The primary outcome was a new postoperative cerebellar diffusion-weighted imaging (DWI) abnormality. Conditional logistic regression stratified by surgeon adjusted for age, maximum extrameatal tumor diameter, cystic morphology, and preoperative hydrocephalus. Operative time was analyzed using linear regression with surgeon fixed effects. The LCMC group had shorter operative time, fewer DWI abnormalities, and lower postoperative dizziness, with comparable gross-total resection and favorable facial-nerve function. After surgeon-stratified adjustment, LCMC remained associated with reduced odds of DWI lesions (adjusted OR 0.22, 95% CI 0.07-0.68; $P = 0.008$) and dizziness (adjusted OR 0.15, 95% CI 0.03-0.76; $P = 0.022$), as well as shorter operative time (-0.77 hours, 95% CI 0.22-1.33; $P = 0.007$). The dizziness finding remains exploratory. Retrospective, non-protocolized route selection precludes causal or superiority conclusions.

Keywords: vestibular schwannoma; retrosigmoid approach; cerebrospinal fluid; cisterna magna; lateral cerebellomedullary cistern; diffusion-weighted imaging

Abbreviations: AAO-HNS, American Academy of Otolaryngology-Head and Neck Surgery; CIs, confidence intervals; CM, cisterna magna; CSF, cerebrospinal fluid; DWI, diffusion-weighted imaging; GTR, gross total resection; HB, House-Brackmann grading system; LCMC, lateral cerebellomedullary cistern; ORs, odds ratios; SD, standard deviation; VS, vestibular schwannoma.

Introduction

Microsurgical resection of large vestibular schwannomas (VSs) remains one of the most technically demanding procedures in skull base surgery. Although advances in microsurgical techniques and intraoperative neurophysiological monitoring have substantially improved surgical safety, adequate brain relaxation remains a prerequisite for successful tumor removal while minimizing cerebellar retraction and cranial nerve injury. Large VSs, generally defined as tumors with a maximum extrameatal diameter greater than 30 mm, frequently compress the brainstem and

fourth ventricle, resulting in elevated intracranial pressure and restricted operative corridors¹. Consequently, achieving early and controlled cerebrospinal fluid (CSF) release is a critical initial step during retrosigmoid surgery.

Controlled CSF drainage after dura opening facilitates cerebellar relaxation, enlarges the cerebellopontine angle corridor, and limits cerebellar retraction. Inadequate relaxation may prolong surgery and increase cerebellar manipulation. Thus, the initial access route for CSF release may influence operative efficiency and postoperative outcomes.

The cisterna magna (CM) and the lateral cerebellomedullary cistern (LCMC) are the two principal anatomical corridors used for CSF release during retrosigmoid surgery. The CM, the largest subarachnoid cistern, communicates with the fourth ventricle through the median and lateral apertures and has traditionally served as the standard site for CSF drainage during posterior fossa procedures²⁻⁴. In contrast, the LCMC is located lateral to the medulla oblongata, between the cerebellar tonsil and the lower cranial nerves, and was popularized by Samii as an alternative route for early CSF release during retrosigmoid VS surgery⁴⁻⁶. Because the LCMC lies directly within the conventional retrosigmoid surgical corridor, it may permit earlier brain relaxation without requiring additional caudal exposure or manipulation of the cerebellar tonsils.

For smaller VSs, either cistern generally provides sufficient CSF drainage to facilitate tumor exposure. However, in patients with large tumors, compression of the fourth ventricle and downward displacement of the cerebellar tonsils frequently obscure access to the CM, often necessitating a more inferior craniectomy or even partial exposure of the foramen magnum. These anatomical constraints may reduce the efficiency of CM opening and increase surgical manipulation before adequate brain relaxation is achieved. In contrast, the LCMC may remain readily accessible after routine dura opening, potentially allowing faster and more controlled CSF release. Despite these theoretical advantages, comparative clinical evidence regarding these initial access routes for CSF drainage during retrosigmoid resection of large VSs remains limited.

To our knowledge, no previous study has directly compared initial CSF release through the CM and LCMC during retrosigmoid resection of large VSs. We therefore performed a retrospective comparative cohort study to evaluate the association of the initial CSF release route with operative efficiency, extent of tumor resection, cranial nerve preservation, and postoperative complications while accounting for potential surgeon-related differences.

Materials and methods

Study Design

This retrospective comparative cohort study was conducted at a tertiary academic medical center. The study protocol was approved by the Institutional Review Board, which waived the requirement for informed consent because of the retrospective study design. The study was conducted and reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement.

A prospectively maintained institutional database was reviewed to identify all consecutive patients who underwent microsurgical resection of large VSs via the retrosigmoid approach between June 2022 and June 2025.

Participating Surgeons and Exposure Assignment

Six fellowship-trained skull base neurosurgeons participated in this study, and each surgeon used both CM and LCMC access during the study period. The initial CSF release route was determined retrospectively from the operative record. Route selection was made at the operating surgeon's discretion and was not governed by a standardized institutional protocol.

All participating surgeons had more than 10 years of independent experience in VS microsurgery before the study period. Standardized microsurgical instruments, intraoperative neurophysiological monitoring, anesthetic management, and perioperative care protocols were used throughout the study period.

Patient Selection

Patients were eligible if they met all of the following inclusion criteria: (1) unilateral VS; (2) maximum extrameatal tumor diameter ≥ 30 mm; (3) primary microsurgical resection via the retrosigmoid approach; and (4) complete clinical, radiological, and follow-up data.

Patients were excluded if they had recurrent VS, neurofibromatosis type 2, previous cranial surgery or radiotherapy, preoperative external ventricular drainage, lumbar CSF drainage, or incomplete follow-up data.

Surgical Procedure

All procedures were performed using a standard retrosigmoid craniectomy under general anesthesia⁷. Continuous intraoperative neurophysiological monitoring, including facial electromyography and brainstem auditory evoked potentials whenever hearing preservation was intended, was routinely employed.

Following dura opening, controlled CSF release was performed as the initial surgical step to achieve adequate cerebellar relaxation. For CM access, the arachnoid membrane over the CM was sharply opened following gentle exposure of the inferior cerebellar surface, allowing gradual CSF drainage (Fig. 1). For LCMC access, the arachnoid membrane over the LCMC was opened between the cerebellar tonsil, lateral medulla, and lower cranial nerves to obtain early CSF release (Fig. 1).

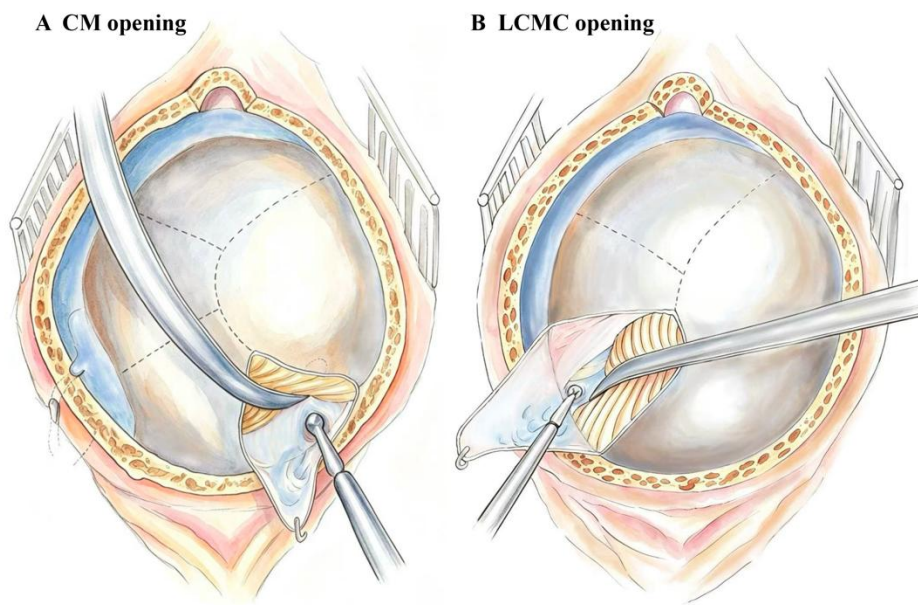


FIG. 1. Schematic comparison of initial CSF release strategies. A: CM opening through the caudal operative corridor. B: LCMC opening through the lateral retrosigmoid corridor. CM = cistern magna; LCMC = lateral cerebellomedullary cistern.

Apart from the initial site of CSF release, all subsequent microsurgical procedures were performed according to identical surgical principles. The primary surgical objective was maximal safe tumor resection while preserving cranial nerve function.

Outcomes

Clinical records, operative reports, and radiological images were reviewed retrospectively. The primary outcome was a new postoperative ipsilateral cerebellar DWI abnormality that was absent preoperatively. Postoperative MRI, including contrast-enhanced T1-weighted imaging and DWI, was routinely performed within 72 hours postoperatively. Two investigators blinded to the CSF-release strategy independently assessed the images.

Secondary outcomes included operative time, GTR, favorable facial nerve function (House-Brackmann grade I-II), postoperative dizziness, CSF leakage, postoperative hydrocephalus and lower cranial nerve dysfunction. GTR was defined as the absence of residual contrast-enhancing tumor on the first postoperative MRI, consistent with current VS practice and international guidelines^{8,9}. Facial nerve function was evaluated using the House-Brackmann (HB) grading system¹⁰. Hearing outcome was assessed according to the American Academy of Otolaryngology-Head and Neck Surgery (AAO-HNS)¹¹.

Statistical Analysis

Continuous variables are reported as mean $\pm$ standard deviation (SD) and were compared with an independent sample *t* test or Mann-Whitney *U* test as appropriate. Categorical variables are reported as counts and percentages and were compared using Fisher's exact tests.

Associations with postoperative cerebellar DWI abnormalities, postoperative dizziness, and favorable facial nerve function were evaluated using separate conditional logistic regression models stratified by surgeon. By conditioning on surgeon, these models estimated route associations from within-surgeon comparisons. Each model included the initial CSF release route and the following prespecified covariates: age, maximum extrameatal tumor diameter (per millimeter), preoperative hydrocephalus, and cystic morphology. Adjusted odds ratios (ORs) with 95% confidence intervals (CIs) were calculated. Total operative time was analyzed using multivariable linear regression with surgeon included as a fixed effect and adjustment for the same patient-and tumor-level covariates.

Because postoperative dizziness occurred in only 14 patients, this analysis was considered exploratory. Firth penalized logistic regression incorporating surgeon indicator variables and the same prespecified covariates was performed as a sensitivity analysis for binary outcomes. Analyses were performed using R software (version 4.3.2; R Foundation for Statistical Computing, Vienna, Austria). All tests were 2-sided, with $P < .05$ considered statistically significant.

Results

Patient Characteristics

A total of 100 patients with large VSs were included in the final analysis (Fig. 2). CM access was used in 53 patients and LCMC access in 47. Each of the 6 surgeons used both routes, with 7 to 10 cases per route for each surgeon (Supplementary Table 1). Baseline demographic and clinical

characteristics are summarized in Table 1. No material between-group imbalance was observed in age, sex, maximum extrameatal tumor diameter, cystic morphology, preoperative hydrocephalus, serviceable hearing, or preoperative facial nerve function (all $P > .05$).

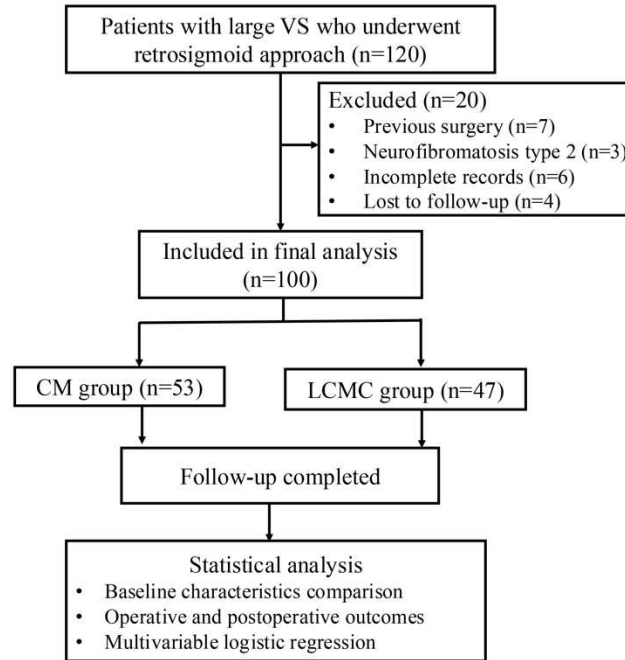


FIG. 2. Study flow diagram. CM = cisterna magna; LCMC = lateral cerebellomedullary cistern; VS = vestibular schwannoma.

Table 1. Baseline Characteristics

Variable	CM group	LCMC group	p-Value
No. of cases	53	47	
Age in yrs			.325
Mean (SD)	53.1(14.3)	55.7(11.2)	
Sex, n (%)			1.000
Female	31 (58.5%)	27 (57.4%)	
Male	22 (41.5%)	20 (42.6%)	
Maximum extrameatal tumor diameter			.365
Mean (SD), mm	39.4 (7.2)	38.2 (5.8)	
Cystic morphology, n (%)	31 (58.5)	25 (53.2)	.687
Preoperative hydrocephalus, n (%)			.526
Yes	20 (37.7%)	14 (29.8%)	
No	33 (62.3%)	33 (70.2%)	
Serviceable hearing*, n (%)	7 (13.2)	6 (12.8)	1.000

Preoperative facial nerve dysfunction *, n (%)	2 (3.8%)	6 (12.8%)	.143
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*Serviceable hearing was defined as AAO-HNS A-B, *Preoperative facial nerve dysfunction was defined as HB $\geq$ III.

Operative and Postoperative Outcomes

Compared with the CM group, the LCMC group had a shorter mean operative time (4.31 ± 1.17 vs 5.21 ± 1.72 hours, $P = .003$). After adjustment for surgeon and prespecified patient- and tumor-level covariates, LCMC access remained associated with a shorter operative time (adjusted mean difference -0.77 hours, 95% CI -1.33 to -0.22; $P = .007$). GTR rates were comparable between the LCMC and CM groups (87.2% vs 84.9%; $P = .781$) (Table 2).

The incidence of new cerebellar DWI abnormalities was lower in the LCMC group than in the CM group (10.6% vs 35.8%, $P = .004$). Postoperative dizziness was also less frequent after the LCMC access (6.4% vs 20.8%, $P = .046$). Favorable facial nerve function occurred in 85.1% and 73.6% of patients, respectively ($P = .219$). No material between-group differences were observed in CSF leakage, postoperative hydrocephalus, or lower cranial nerve dysfunction (Table 2).

Table 2. Operative and Postoperative Outcomes

Variable	CM (n=53)	LCMC (n=47)	P-value
Intraoperative outcome			
Operative time			
Mean (SD), hours	5.21 (1.72)	4.31 (1.17)	.003
Gross total resection, n (%)	45 (84.9)	41 (87.2)	.781
Primary outcome			
Postoperative cerebellar DWI abnormalities, n (%)	19 (35.8)	5 (10.6)	.004
Secondary outcome			
Favorable facial nerve function (HB I-II), n (%)	39 (73.6)	40 (85.1)	.219
Postoperative dizziness, n (%)	11 (20.8)	3 (6.4)	.046
Lower cranial nerve dysfunction, n (%)	1 (1.9)	2 (4.3)	.599
Postoperative complications			
CSF leakage, n (%)	1 (1.9)	0 (0.0)	1.000
Postoperative hydrocephalus, n (%)	12 (22.6)	9 (19.1)	.807

Values are mean $\pm$ SD or number (%). DWI = diffusion-weighted imaging; HB = House-Brackmann.

Multivariable Logistic Regression Analysis

In conditional logistic regression stratified by surgeon and adjusted for age, maximum extrameatal tumor diameter, preoperative hydrocephalus, and cystic morphology, LCMC access was associated with lower odds of a postoperative cerebellar DWI abnormality (adjusted OR 0.22, 95%

CI 0.07-0.68; $P = .008$) and postoperative dizziness (adjusted OR 0.15, 95% CI 0.03-0.76; $P = .022$).

LCMC access was not significantly associated with favorable facial nerve function after surgeon-stratified multivariable adjustment (adjusted OR 2.08, 95% CI 0.71-6.12; $P = .184$) (Table 3 and Fig. 3). Firth penalized sensitivity analyses produced similar effect estimates for all 3 binary outcomes (Supplementary Table 2).

Table 3. Surgeon-adjusted multivariable analyses for LCMC versus CM access

Outcome	Effect measure	Estimate	95% CI	P-value
Cerebellar DWI abnormality	Adjusted OR	0.22	0.07-0.68	.008
Postoperative dizziness	Adjusted OR	0.15	0.03-0.76	.022
Favorable facial nerve function	Adjusted OR	2.08	0.71-6.12	.184
Operative time	Adjusted mean difference, hours	-0.77	-1.33 to -0.22	.007

Binary outcomes were analyzed using conditional logistic regression stratified by surgeon. Operative time was analyzed using linear regression with surgeon fixed effects. All models were adjusted for age, maximum extrameatal tumor diameter, cystic morphology, and preoperative hydrocephalus.

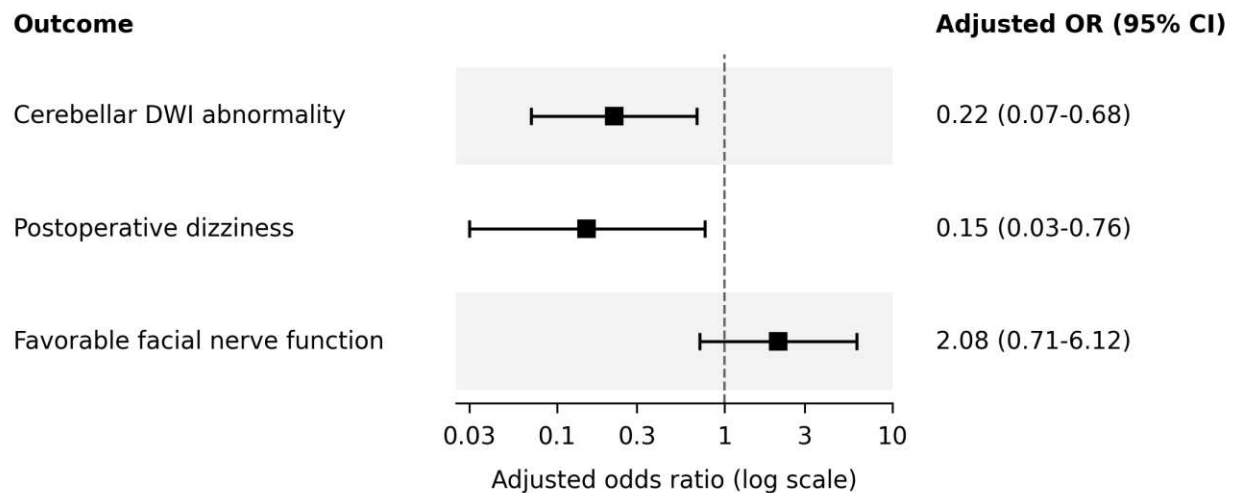


FIG. 3. Surgeon-stratified multivariable analyses of postoperative outcomes associated with LCMC versus CM access. Squares represent adjusted odds ratios (ORs), and horizontal lines indicate 95% confidence intervals (CIs). Conditional logistic regression models were stratified by surgeon and adjusted for age, maximum extrameatal tumor diameter, preoperative hydrocephalus, and cystic morphology. DWI = diffusion-weighted imaging; HB = House-Brackmann.

Among the remaining covariates, preoperative hydrocephalus showed a nonsignificant association with lower odds of favorable facial nerve function (adjusted OR 0.35, 95% CI 0.12-1.05; $P = .062$). No other covariate was significantly associated with the evaluated binary outcomes.

Surgeon-Adjusted and Sensitivity Analyses

All 6 surgeons contributed patients to both exposure groups, and the distribution of CM and LCMC cases within surgeon was sufficiently overlapping for within-surgeon analysis (Supplementary Table 1). Conditional logistic regression stratified by surgeon therefore accounted for stable between-surgeon differences while estimating the route association from patients operated on by the same surgeon.

In Firth penalized sensitivity models that incorporated surgeon indicator variables, the adjusted ORs associated with LCMC access were 0.25 (95% CI 0.08-0.73; $P = .011$) for postoperative cerebellar DWI abnormalities, 0.20 (95% CI 0.05-0.79; $P = .022$) for postoperative dizziness, and 1.95 (95% CI 0.69-5.54; $P = .209$) for favorable facial nerve function. These estimates were directionally consistent with the primary surgeon-stratified models.

Representative Cases

Figure 4 illustrates a representative CM-access case with a postoperative ipsilateral cerebellar DWI abnormality. Figure 5 illustrates a representative LCMC-access case without a postoperative cerebellar DWI abnormality. These cases are presented for imaging illustration and were not used for comparative inference.

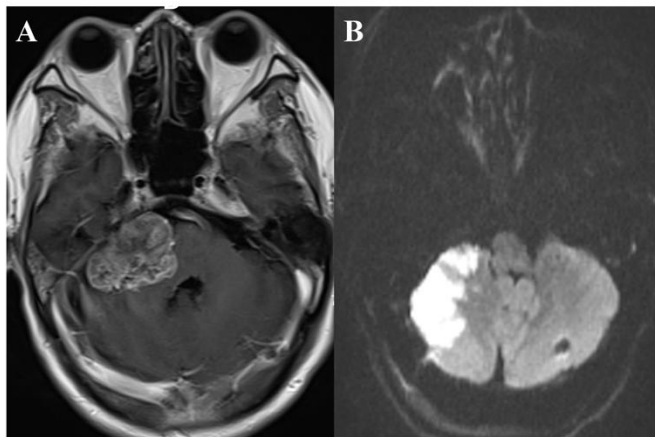


FIG. 4. Representative case from the CM group. A: Preoperative axial T1-weighted MR image obtained with gadolinium contrast showing a large right-sided VS. B: Postoperative axial DWI showing extensive hyperintensity in the ipsilateral cerebellar hemisphere after retrosigmoid

resection with initial CSF release through the CM. CM = cisterna magna; VS = vestibular schwannoma.

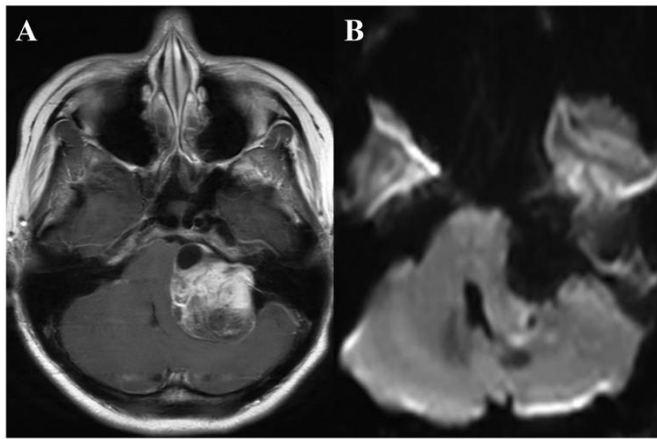


FIG. 5. Representative case from the LCMC group. A: Preoperative axial T1-weighted MR image obtained with gadolinium contrast showing a large, left-sided VS. B: Postoperative axial DWI image showing no corresponding cerebellar signal abnormality after retrosigmoid resection with initial CSF release through the LCMC. LCMC = lateral cerebellomedullary cistern; VS = vestibular schwannoma.

Discussion

The present study evaluated the association between the initial surgical access route used for CSF release and outcomes after retrosigmoid resection of large VSs. Compared with CM access, LCMC access was associated with fewer postoperative cerebellar DWI abnormalities and shorter operative time after accounting for surgeon and prespecified patient- and tumor-level covariates. Postoperative dizziness was also less frequent, although the limited number of events makes this finding exploratory. GTR and favorable facial nerve function rates were comparable between groups.

Adequate cerebellar relaxation before tumor manipulation is fundamental to retrosigmoid surgery. Contemporary VS surgery emphasizes maximal safe resection, dynamic retraction, neurophysiological monitoring, and cranial nerve preservation^{12,13}. Early cisternal CSF release enlarges the operative corridor, yet the influence of the initial access route has received little clinical investigation.

The CM and LCMC communicate within the same posterior fossa subarachnoid space. Accordingly, our results should not be interpreted as evidence that drainage from one cistern produces a different physiological CSF decompression than drainage from the other. The

hypothesized distinction concerns the surgical route before effective CSF release. In a crowded posterior fossa, reaching the CM through a caudal corridor may require additional inferior exposure, whereas the LCMC may be accessible through the lateral retrosigmoid trajectory. This approach is consistent with the operative philosophy described in large microsurgical series, in which early lateral cisternal opening is used to obtain cerebellar relaxation before substantial tumor manipulation^{5,6}. Nevertheless, direct clinical comparisons of the CM and LCMC as the initial site of CSF release remain limited.

The most consistent finding in this cohort was the lower incidence of new postoperative ipsilateral cerebellar DWI abnormalities in the LCMC group. The localization of all abnormalities to the ipsilateral cerebellar hemisphere, rather than the brainstem or supratentorial compartment, supports a possible relationship with local surgical manipulation. Potential mechanisms include transient impairment of regional perfusion, compression or stretching of small cerebellar vessels, venous outflow disturbance, and mechanical stress related to cerebellar retraction. Earlier CSF release through the LCMC could theoretically reduce these effects by allowing the cerebellum to fall away from the petrous surface before substantial exposure or tumor dissection. The higher incidence of ipsilateral cerebellar DWI abnormalities in the CM group may reflect greater local mechanical stress and transient perfusion disturbance associated with additional caudal exposure before CSF release. However, cerebellar retraction and perfusion were not directly measured, and this mechanism remains hypothetical.

The lower incidence of postoperative dizziness observed in the LCMC group provides potential clinical context for the imaging findings. Dizziness after VSs surgery is multifactorial and may result from cerebellar dysfunction, postoperative edema, headache, or preexisting vestibular symptoms^{14,15}. In this cohort, postoperative dizziness was more frequent among patients with DWI abnormalities than among those without them. Nevertheless, dizziness was identified from clinical records rather than measured using a validated scale, and only 14 patients experienced this outcome. The association should therefore be regarded as exploratory and does not establish a direct mechanistic relationship.

LCMC access was not independently associated with favorable facial nerve function, consistent with the multifactorial nature of nerve preservation. Tumor size and consistency, arachnoid adhesions, nerve displacement, surgeon experience, and neurophysiological monitoring influence postoperative facial nerve outcomes¹⁶⁻¹⁸. The initial CSF release route is only one component of

exposure and may be less important than the tumor-nerve relationship during dissection. Large VS cohorts and pooled analyses similarly identify baseline neurological status, tumor burden, and extent of resection as major determinants^{19,20}.

The shorter operative time associated with the LCMC strategy may reflect more efficient initial exposure. The potential clinical relevance of reducing local manipulation is supported by prior comparative evidence linking the retrosigmoid route and longer tumor resection time to greater postoperative cerebellar edema and related morbidity²¹, as well as by broader descriptions of cerebellar, brainstem, and vascular complications after retrosigmoid VS surgery²². Earlier lateral CSF release could reduce repeated adjustments in cerebellar retraction and facilitate entry into the cerebellopontine angle. However, total operative duration encompasses tumor dissection, hemostasis, and wound closure and therefore represents only an indirect measure of the efficiency of initial CSF release. Future prospective studies should record exposure-specific time intervals, including the time from dura opening to CSF release, satisfactory cerebellar relaxation, and initial tumor exposure, to more directly compare the technical efficiency of the two routes.

The within-surgeon design substantially reduces the structural confounding that would occur if different surgeons exclusively used different routes. Conditional logistic regression stratified by surgeon accounts for stable between-surgeon differences, such as baseline operative experience and habitual workflow. However, route selection was not protocolized. Within an individual surgeon's practice, anatomical accessibility, posterior fossa crowding, perceived operative difficulty, or other undocumented factors may have influenced route selection and outcomes. Surgeon adjustment therefore strengthens the association but does not eliminate confounding by indication or establish causality.

Study limitations

Several limitations should be acknowledged. First, the retrospective single-center design remains susceptible to selection bias and residual confounding. Although every surgeon used both routes and the analyses were stratified by surgeon, route selection was not governed by a standardized protocol, and the specific rationale for selecting CM or LCMC access was not consistently documented. Consequently, residual confounding by anatomical accessibility, perceived operative difficulty, and surgeon preference cannot be excluded. Second, the modest sample size and limited number of outcome events, particularly for postoperative dizziness, reduce model precision; the

dizziness findings should be considered exploratory despite consistent Firth sensitivity estimates. Third, dizziness was not assessed using a standardized validated instrument, and DWI abnormalities represent an imaging finding rather than a specific pathological diagnosis. Finally, CSF volume, time from dural opening to effective CSF release, degree of cerebellar relaxation, retraction force, and cerebellar perfusion were not directly measured. Prospective studies using protocolized or randomized route allocation within surgeon and standardized exposure-specific measurements are needed.

Conclusions

In patients undergoing retrosigmoid resection of large VSs, initial CSF release through the LCMC was associated with fewer postoperative cerebellar DWI abnormalities and shorter operative time after accounting for surgeon. The association with postoperative dizziness was directionally consistent but should be considered exploratory. Because route selection was retrospective and nonprotocolized, these results do not establish causality or superiority. Prospective within-surgeon studies with protocolized or randomized route allocation are warranted.

Disclosures

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

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Author Contributions

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