

Original Article

Drainage patterns of the superficial middle cerebral vein: Effects on perioperative managements of petroclival meningioma

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Abstract

Background: Although the superficial middle cerebral vein (SMCV) usually connects with the cavernous sinus, there are several anatomical variations. We determined whether differences in SMCV drainages patterns affected the perioperative management of petroclival meningioma.

Methods: The subjects included 17 patients (4 men; 13 women) who underwent resection of a petroclival meningioma. SMCV drainage patterns were classified into four groups according to angiographic findings: (1) The SMCV connected with the cavernous sinus (Group A); (2) The SMCV was either absent or connected directly with the superior sagittal or transverse sinus through the cortical veins (Group B); (3) The SMCV turned downward and connected with the pterygoid plexus through the sphenobasal vein (SpBV, Group C); and (4) The SMCV ran across the bottom of the middle fossa and connected with transverse sinus via the sphenopetrosal sinus (SpPS, Group D).

Results: In all 9 patients in Group A, the SMCV drainage pattern did not affect any aspect of perioperative management. In contrast, SMCV drainage patterns in 3 of 4 patients in Group B and both patients in Groups C and D had an effect on perioperative management, indicating a significant impact of variations in SMCV drainage patterns ($P < 0.005$). In 2 patients in Group C and 1 in Group D, the operating corridor provided by a transpetrosal approach was small in order to preserve the SpBV or SpPS. In the other patient in Group D, an anterior transpetrosal approach was not selected preoperatively because the SpPS would likely be injured during surgery.

Conclusions: In cases, where the SMCV directly connects with superior sagittal or transverse sinus, SpBV or SpPS, surgeons have to meticulously select a safe and effective approach and take measures to preserve the SpBV or SpPS during surgery.

Key Words: Petroclival meningioma, petrosal approach, sphenobasal vein, sphenopetrosal sinus, superficial middle cerebral vein

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INTRODUCTION

The superficial middle cerebral vein (SMCV) typically either connects with the proximal sphenoparietal sinus and then flows into the cavernous sinus or directly drains into the cavernous sinus.^[2,9] However, in some cases, the SMCV turns downward and connects with the pterygoid plexus through the sphenobasal vein (SpBV) at the foramen ovale, or runs across the pyramidal ridge and connects with transverse sinus via the sphenopetrosal sinus (SpPS) or vein. In additional cases, a definite SMCV is absent, or the SMCV directly connects with the superior sagittal or transverse sinus via the cortical veins.^[2]

A transpetrosal approach has been widely used in surgical treatment for petroclival meningioma. A key procedure of this operation is cutting the cerebellar tentorium and dura along the bottom of the middle fossa to create a wide exposure of both supra- and infra-tentorial regions. In a patient with an SMCV connection to the SpPS, incision of the tentorium is likely to disturb the SpPS drainage from the temporal lobe.^[6,10] In patients with an SMCV connection with the SpBV, epidural procedures around the foramen ovale required in an anterior transpetrosal approach may injure the SpBV and result in interrupted venous drainage.^[3,4] In this study, we retrospectively determined whether the venous drainage patterns of the SMCV affected perioperative management in patients who underwent surgery for petroclival meningioma.

PATIENTS AND METHODS

Patient population

The study included 17 patients (4 men, 13 women) with petroclival meningioma, who were treated surgically at the University of Niigata during a period, from November 2005 to December 2013. Clinical data for patients are outlined in Table 1. Patient age at surgery ranged from 34 to 76 years (mean, 53.7 years). Tumor size, which was defined as the largest lesion diameter, ranged from 22 to 60 mm (mean, 45.1 ± 11.5 mm). This case series included patients with “true petroclival meningioma”^[1] and “sphenopetroclival meningioma.” Sphenopetroclival meningiomas extend through both cavernous sinuses, with en plaque extension along the ventral posterior fossa dura and tentorium, and sometimes involve the optic nerve, or the internal carotid artery. The tumor was located on the right side in 8 patients and on the left side in 9. The most common presenting sign was hearing loss (71%) followed by trigeminal nerve impairment (53%), cerebellar ataxia (29%), pyramidal tract symptoms (24%), and mental dullness due to hydrocephalus (18%). One patient (Patient 8) displayed facial palsy, as well as hearing loss and cerebellar ataxia. Another patient (Patient 9) presented with increased

intracranial pressure signs, such as headache and vomiting.

Superficial middle cerebral vein drainage patterns

Conventional angiography was performed in all patients. SMCV drainage patterns were classified into four groups according to these angiographic findings [Figure 1]: (1) The SMCV connected with the cavernous sinus [Group A in Figure 1a]; (2) The SMCV was absent or directly connected with the superior sagittal or transverse sinus via the cortical veins [Group B in Figure 1b]; (3) The SMCV turned downward and connected with the pterygoid plexus via the SpBV [Group C in Figure 1c]; and (4) The SMCV ran across at the bottom of the middle fossa and connected with transverse sinus via the SpPS [Group D in Figure 1d]. This classification system was based on a report in which SMCV drainage patterns were classified into seven types based on embryologic development and three-dimensional (3D) computed tomography (CT) angiography.^[8] The sphenoparietal and cavernous types described in the report correspond to Group A in our classification system; the squamosal and undeveloped types correspond to Group B; the emissary and superior petrosal types correspond to Group C, and the basal type correspond to Group D. Accordingly, in our series, 9 of 17 patients (52%) were assigned to Group A, 4 patients (24%) were assigned to Group B, and 2 patients (12%) each were assigned to Groups C and D [Table 1].

Surgical procedures

Based on the tumor location and size, SMCV drainage patterns, and preoperative symptoms, a range of surgical approaches were considered for each patient [Table 1]. The anterior transpetrosal approach was applied in 6 patients, the retrosigmoid approach in 4, and the combined transpetrosal approach in 3. The posterior transpetrosal, orbitozygomatic (OZ) and anterior transpetrosal, OZ and combined transpetrosal, or infralabyrinthine, and transcondylar approach were carried out in 1 patient each.

Evaluations

We retrospectively determined whether SMCV drainage patterns (four groups) affected perioperative management based on each patient's medical records. Perioperative management comprised preoperative selection of the surgical approach, limitations of surgical fields or changes in surgical manipulation to ensure preservation of the drainage veins during surgery, unusual venous bleeding intraoperatively, and unpredictable postoperative events that were likely attributable to injury to drainage veins of the SMCV. For statistical analysis, a χ^2 test and Fisher's exact probability test were used. A $P < 0.05$ was defined as significant.

Table 1: Summary of patients with petroclival meningioma in our case series

Patient No	Age/sex	Side	Size (mm)	Pre-signs	Drainage pattern	Surgical approach	Effects on operation	Additional treatments	Follow-up periods (M)	Final KPS
1	42/F	R	48	V	A	Retrosigmoid	No	2 operations, GKS	98	80
2	55/M	L	42	VIII	D	Post. petrosal	Intra-	2 operations, GKS	89	80
3	54/F	L	26	V, VIII	B	Ant. petrosal	Post-	No	52	90
4	57/F	L	47	V, VIII	A	Comb. petrosal	No	GKS	74	100
5	61/M	L	44	V, VIII, pyramidal	A	Ant. petrosal	No	1 operation, GKS	72	80
6	48/F	L	60	VIII, mental	B	Comb. petrosal	Intra-	No	60	60
7	41/F	R	50	VIII, cerebellar	C	Ant. petrosal	Intra-	1 operation	54	80
8	76/F	L	57	VII, VIII, cerebellar	A	Retrosigmoid	No	1 operation, GKS	15	60
9	34/F	R	60	V, VIII, IICP	B	OZ and ant. petrosal	No	2 operations, GKS	31	80
10	55/F	L	33	VIII	A	Retrosigmoid	No	No	26	100
11	64/M	R	41	V, VIII, mental, pyramidal	A	Ant. petrosal	No	No	7	40
12	56/F	R	33	V, cerebellar	B	Ant. petrosal	Intra-	No	23	100
13	74/M	R	58	Cerebellar, pyramidal, mental	A	Comb. petrosal	No	GKS	17	60
14	47/F	R	48	Cerebellar, pyramidal	A	OZ, comb. petrosal	No	1 operation, GKS	15	80
15	52/F	L	55	VIII	A	Infralab. and transcondylar	No	No	8	80
16	39/F	L	22	V	C	Ant. petrosal	Intra-	No	6	80
17	58/F	R	42	V, VIII	D	Retrosigmoid	Pre-	No	39	80

GKS: Gamma knife surgery; KPS: Karnofsky performance scale, OZ: Orbitozygomatic, IICP: Increased intracranial pressure, F: Female, M: Male

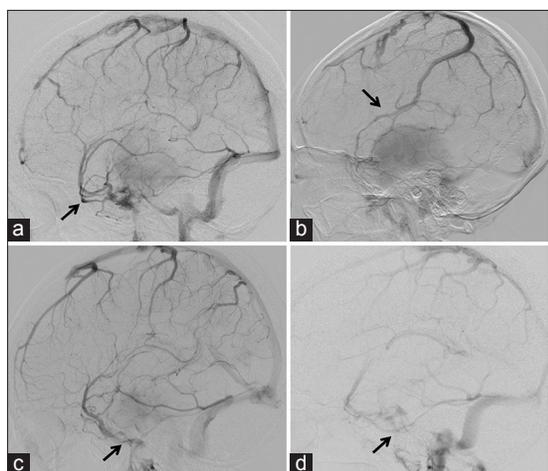


Figure 1: Examples of the four types of superficial middle cerebral vein drainage patterns. (a) Carotid angiogram in venous phase showing the superficial middle cerebral vein draining into the cavernous sinus (arrow). (b) Image of a superficial middle cerebral vein connecting with the superior sagittal sinus via the cortical bridging vein (arrow). (c) Image of a superficial middle cerebral vein turning downward and connecting with the pterygoid plexus via the sphenobasal vein (arrow). (d) Image of a superficial middle cerebral vein running across the bottom of the middle fossa and connecting with the transverse sinus via the sphenopetrosal sinus (arrow)

RESULTS

Surgical results

Total tumor removal was achieved in only 1 of 17 patients [Patient 3 in Table 1]. Two of 17 patients (Patients 12 and 16) underwent subtotal removal (more than 90% removal) and the remaining 14 patients underwent partial removal (<90% removal).

In 3 of these 14 patients, 2 follow-up surgeries and gamma knife surgery (GKS) were performed for the residual tumor. Another 3 patients underwent one surgery and GKS after the initial surgery. Two patients underwent only one additional surgery and one underwent only GKS. The remaining 5 patients have thus far received no additional treatment for the residual tumor so far [Table 1]. The mean follow-up period after the initial surgery was 40.4 months (range, 6–98 months). In all patients, residual tumor regrowth was not observed in the final magnetic resonance imaging studies. The Karnofsky performance status ranged from 40 to 100 (mean, 78.1 ± 16.4) at the final examinations [Table 1].

Effects of superficial middle cerebral vein drainage patterns on perioperative managements

In all 9 patients assigned into Group A, the SMCV drainage patterns did not affect any aspects of perioperative management. In contrast, SMCV drainage patterns affected perioperative management in 3 of 4 patients in Group B and all patients in Groups C and D indicating a significant effect of SMCV drainage patterns ($P < 0.005$). In total, no patients in Group A versus 7 of 8 patients (87.5%) in the other groups had at least one adverse event or surgical complication during perioperative management ($P < 0.001$).

In Group B, Patient 3 [Table 1] experienced postoperative venous hemorrhagic infarction, likely caused by poorly developed venous drainage in the temporal lobe coupled with compression of the temporal lobe by a spatula during surgery. In Patient 12 [Figure 2a], a definite SMCV was absent, and the basal vein ran into the cerebellar tent

connecting with the transverse sinus [Figure 2b]. When the cerebellar tent was cut in making an anterior petrosal approach, we had to take measures to preserve the basal vein [Figures 2c and d]. In Patient 6, who had a large petroclival meningioma (tumor size: 60 mm), internal carotid arterial angiography showed that the SMCV directly connected to the transverse sinus. Although, we tried to remove the tumor by a combined transpetrosal approach, we had to discontinue tumor resection due to massive bleeding from intraosseous veins present in the middle fossa. After surgery, the patient presented no obvious postoperative venous complications. Patient 9, who presented a drainage pattern in which the SMCV connected with the sagittal sinus via the cortical veins was the only patient, in whom there were no complications of perioperative management due to drainage patterns.

In both patients assigned to Group C (Patients 7 and 16), we were unable to attain a wider operative field and required access via drilling the petrous bone, because an epidural approach was not used around the foramen ovale due to the presence of a SpBV connection. In Patient 7, in particular, it was difficult to arrest venous bleeding around the foramen ovale due to the SpBV connection [Figure 3a and b]. Neither patient experienced any complications related to venous drainage of the SMCV.

In Patient 2 in Group D, we attempted to remove the tumor through a posterior transpetrosal approach, but the operating field was too narrow as the middle fossa dura was not cut in order to preserve the SpPS. In the other Group D patient (Patient 17), we did not select an anterior transpetrosal approach because the SpPS was

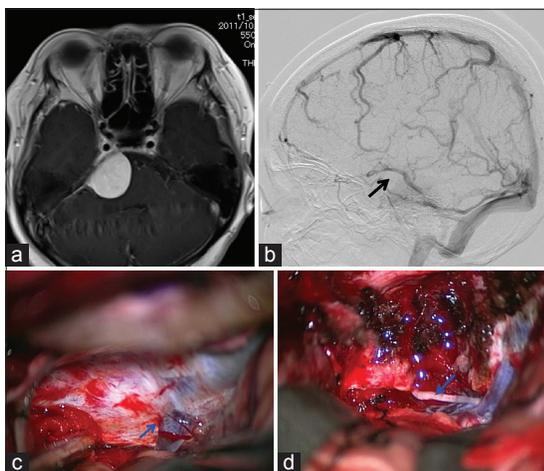


Figure 2: Example of a case in which the superficial middle cerebral vein was absent. (a) T1-weighted magnetic resonance imaging with contrast medium showing a right petroclival meningioma (Patient 12). (b) Right carotid angiogram in the venous phase showing that the superficial middle cerebral vein is absent, and the basal vein runs into the cerebellar tent and connects with the transverse sinus (arrow). (c) The Rosenthal basal vein (blue arrow) running into the cerebellar tent is visualized. (d) Tentorium incision with preservation the basal vein exposed the tumor and trochlear nerve (blue arrow)

identified preoperatively [Figure 4a and b]. Instead, a retrosigmoid approach was used, and anterior parts of the tumor could not be resected.

DISCUSSION

In the present study, no petroclival meningioma cases in which the SMCV connected with the cavernous sinus manifested any complications of pre-, intra-, or post-operative management of surgical treatment. In contrast, the complications of perioperative management were almost always encountered for patients with a SpBV or SpPS connection, or an SMCV that directly connected with either the superior sagittal or transverse sinus. In patients with these latter patterns, the surgical procedure was complicated by the need to meticulously select an appropriate approach for removal of the petroclival meningioma that preserved the SpBV or SpPS.

Patients in whom the SMCV directly connected with the superior sagittal sinus via the cortical vein seemed to have the advantage of it being relatively simple to preserve venous drainage of the temporal lobe using an anterior or posterior transpetrosal approach. Patient 9 provides an example of this drainage pattern, and there were no problems encountered with venous drainage in the temporal lobe during surgery. In contrast, preventing bleeding during operations in which there was an unusual SMCV venous pattern was challenging. Indicating that this is a fairly common clinical issue, a study that classified SMCV variations using 3DCT reported a 9% incidence of undeveloped SMCV,^[8] in which case the SMCV is absent and venous drainage extends upward and backward into the superior sagittal or transverse sinus. As an example from our case series, surgeons encountered massive intraoperative bleeding from intraosseous veins present in Patient 6 and these veins could not be observed by preoperative conventional angiography. In addition, poor development of venous drainage in

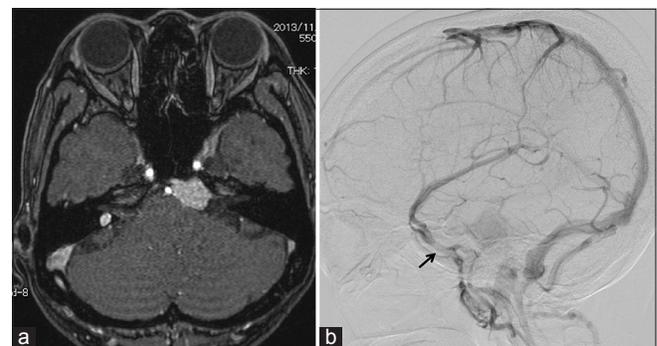


Figure 3: Example of a superficial middle cerebral vein connecting to the sphenobasal vein. (a) T1-weighted magnetic resonance imaging with contrast medium showing a left petroclival meningioma (Patient 7). (b) Left carotid angiogram in venous phase showing the superficial middle cerebral vein connecting with the pterygoid venous plexus via the sphenobasal vein (arrow)

the temporal lobe of Patient 3 likely led to a cerebral contusion caused by spatula compression. Therefore, in cases lacking a definitive SMCV, surgeons may need to take care to elevate gently the temporal lobe by spatula and carefully account for unpredicted bleeding from the veins around the middle fossa. Future studies with larger sample sizes are needed to determine whether there are advantages in perioperative management using a petrosal approach in the case of direct connections between the SMCV and the superior sagittal sinus.

Although the basal veins flowed into the great vein of Galen in most cases, these veins rarely course along the medial edge, center, or lateral edge of the tentorium. However, basal vein drainage flow into medial or lateral tentorial sinus was observed in 5% of subjects in a 3DCT angiography study.^[7] In the present series, there was 1 patient (Patient 12) in whom the basal vein flowed into the transverse sinus through the center of the tentorium. When there is lateral or medial tentorial sinus flow, preservation of these sinuses during tentorium incision is required, as is a subtemporal transtentorial, occipital transtentorial, or transpetrosal approach.

The SpBV is the main drainage vessel of the SMCV in 11–18% of individuals.^[3,8,9] Surgical interruption of the SpBV by epidural manipulations in making the anterior transpetrosal approach likely injures the temporal lobe. If a SpBV has developed, surgeons must drill the petrous apex without making an epidural approach around the foramen ovale, through which the SpBV runs and connects with the pterygoid plexus.^[3] In the 2 patients with a SpBV in our case series, our only option was to drill the petrous apex and remove the tumor through a narrow operative corridor. Recently, a new method involving epidural anterior petrosectomy with subdural visualization of the SpBV was reported.^[4] In this procedure, the convexity dura mater of the temporal lobe was cut and retracted the anterior part of the temporal lobe subdurally. After which the SpBV could be visualized subdurally, the basal dura mater posterior

to the SpBV was cut. The posterior part of the temporal lobe was then retracted epidurally. This modified anterior transpetrosal approach probably provides both preservation of the SpBV and a wider operative corridor.

In 2–10% patients, a SpPV connection is present, in which case the SMCV runs across the bottom of the middle fossa and connects with transverse sinus via the SpPS.^[6-9] Based on embryologic anatomy, the SpPS provides the extent of communication to the transverse sinus with the primitive tentorial sinus.^[8] To preserve the SpPS in an anterior petrosal approach, the tentorial incision must be performed on the side medial to the SpPS,^[10] which resulted in a narrow operative window. Some studies have stated that surgeons should abandon a transpetrosal approach even for the petroclival region in cases in which a SpPS connection is present.^[6] Indeed, in 1 patient (Patient 17), we did not use a transpetrosal approach, but rather selected a retrosigmoid approach to preserve essential venous drainage. In the other operation involving a SpSV connection (in Patient 2), incision of the cerebellar tent along the SpPS provided limited though sufficient space both medial and lateral to the SpPS to remove the residual tumor. If a transpetrosal approach is used in patients, in which, a SpPS connection is present, it is important to devise a strategy that allows resection of the cerebellar tent, while preserving venous drainage running along the middle fossa floor.

Based on the results, there likely are disadvantages in an anterior petrosal approach for patients in Groups B, C, and D. For patients in Groups B and D, a posterior petrosal approach likely has disadvantages, as well [Table 2]. A transpetrosal approach carries a higher risk of venous complications caused by injuring the drainage pathway of not only the SMCV, but also the superior petrosal vein, especially during the tentorium incision. Preoperative 3DCT venography was useful in evaluating the drainage site of the superior petrosal vein into the petrosal sinus.^[5] In devising the surgical approach for petroclival meningioma patients in Groups B, C, and D, it should be determined whether a transpetrosal approach is possible and if a retrosigmoid approach would

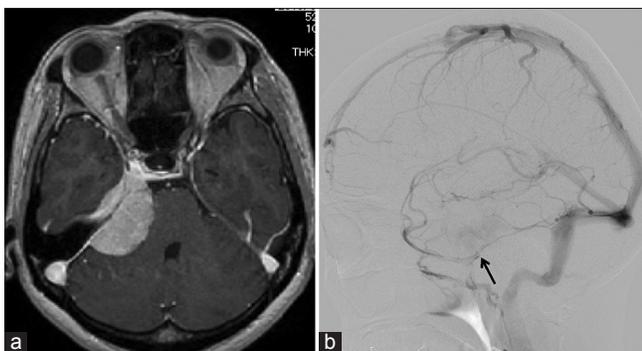


Figure 4: Example of a superficial middle cerebral vein connecting the sphenopetrosal sinus. (a) T1-weighted magnetic resonance imaging with contrast medium showing a right petroclival meningioma (Patient 17). (b) Right carotid angiogram in venous phase showing the superficial middle cerebral vein connecting with the transverse sinus via the sphenopetrosal sinus (arrow)

Table 2: Surgical approaches and venous drainage patterns

Surgical approach	Favorable drainage pattern	Unfavorable drainage pattern
Anterior petrosal	A	B*, C, D
Posterior petrosal	A	B*, D
Combined petrosal	A	B*, C, D

A: The SMCV connected with the cavernous sinus, B: The SMCV was absent or directly connected with the superior sagittal or transverse sinus via the cortical veins, C: The SMCV turned downward and connected with the pterygoid plexus via the sphenobasal vein, D: The SMCV ran across the bottom of the middle fossa and connected with the transverse sinus via the sphenopetrosal sinus. *Except for patterns with direct connections between the SMCV and superior sagittal sinus. SMCV: Superficial middle cerebral vein

be better in order to minimize the risk of injuring the venous drainages of the SMCV and superior petrosal vein.

CONCLUSIONS

Except for patients in whom the SMCV connects with the cavernous sinus, venous drainage patterns of the temporal lobe likely lead to more complicated pre-, intra-, and post-operative management of surgical treatments for petroclival meningioma. When a SpBV connection is present, surgeons should consider strategies that do not injure the vein around to the foramen ovale during an anterior petrosal approach. In cases, in which a SpPS connection is present, a tentorial incision that preserves venous drainage and a transpetrosal approach are needed.

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